

**CUTTING GLASS CREATIVELY WITH
ABRASIVE WATER JET – AN OVERVIEW**

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ABSTRACT

This paper intends to give an overview to the research that has been carried during the past four years relating to cutting glass for creative industries using abrasive waterjet.

Glass is used in an increasing variety of ways in art and architecture. Artists employing this material seek to work it into creative and complex forms. It needs to be cut, manipulated and moulded into shape. The current cutting practices within most glass artists' studios are relatively basic, making some glass applications difficult or impossible to execute. The development of new technologies such as waterjet enables new cutting methods to be incorporated into the glass artist's practice. Within this developing context, the aims of the research were:

- To establish and demonstrate parameters of practice in cutting glass using waterjet for creative purposes
- To produce a substantial body of practical work exploring the creative uses of waterjet cutting with written exposition.

The research was initiated with a series of cutting trials undertaken with companies both in the U.K. and Germany. The trials investigate the parameters and quality of cutting from a variety of glass types used commonly within studio practice. This laid the groundwork for the artworks and served to gain a unique 'intimacy' with the machine.

The investigation explores and enhances the practical and creative parameters through 'informed play' using the waterjet process. This was achieved by generating a series of artworks by the researcher and facilitating those of other artists.

The development of personal artworks and case studies were undertaken in parallel to extend and exemplify an understanding of the possibilities of the creative use of waterjet and glass. The resulting artworks encompassed the three main areas of glass practice: Architectural, Kiln-work, and Hot glass. The artworks have been exhibited in national and international contexts.

The important characteristics of risk, intimacy and process have been explored to enable a model of practice to be developed enabling successful creative application of waterjet.

The research consisted of innovative artwork using cutting, milling and piercing with written exposition; which combined form a model of practice which serves to extend the perceptions of this technology that others may build upon.

1 INTRODUCTION

Abrasive waterjet has become a creative tool in the cutting of glass artistically, helping to further extend the parameters of the material and process within the field of art, design and architecture. This paper explains an overview of the research carried out at the University of Sunderland through case studies and personal development of artworks and the resulting

2 LITERARY REVIEW

As part of this research there was a need to establish what had been cut before what waterjet could and what artistically had been done previously. To help this assessment reference material was collected and each of the case studies analysed to help show how the waterjet process may be applied creatively. It was necessary to show the need of applying the waterjet process within the development of glass cutting and how the process may benefit the glass artist through the history and development of glass cutting. Each of the case studies and own work were documented detailing all aspects of procedures and difficulties resulting from the application of using the waterjet process.

In having produced a body of artwork and case studies it is necessary to position of the work in the context of what has been before.

3 MATERIAL TESTING

The tests were undertaken through industrial liaison with two companies, Bhr Group in the United Kingdom and Ingersol Rand in Germany.

Types of glass used

The following types of glass were chosen:

- **‘Artista’ Glass 6mm** A transparent manufactured glass produced in Germany, quite brittle to cut manually.
Increasingly used by glass artists, as a base glass for frits and powders and compatible with several ranges of glass.
- **Laminated soda-lime glass** Two sheets of soda lime with a layer of polymer resin in between. The glass is stronger and can withstand an impact. Used generally within architecture and manufactured on a huge worldwide scale. An example is case study one: *‘Angel wings’*.
- **4mm soda lime (float)** Used generally within architecture and increasingly creatively with other products and techniques such as slumping, fusing, painting.

- **Antique ‘Flash’ glass** This is hand-blown in a cylinder and then flattened, not always perfectly flat. It consists of a layer of coloured glass covering a substrate. The thickness is inconsistent, making cutting difficult¹. This glass is expensive, hence wastage should be minimal. Its thickness is approximately 3-8mm.
- **Lead glass ingots** Thick cast blocks made from Lead crystal. Uneven in thickness and not easily cut, especially manually, complicated cutting is not easily achieved without the involvement of several processes. The ingots are approximately 30/35mm thickness.

The types of glass chosen were those that are used frequently within architectural studio practice. It was also important to choose a range of glasses that represent a cross-section of the glass used within artist’s studios.

The aim of the investigation was focused on how to obtain the best quality of cut to reduce the need for further applications e.g. ‘linishing’². This is very different to the commercial applications of this process where the emphasis is on speed to ensure effective cutting at maximum efficiency.

Definitions of a high quality cut

The quality of the cutting is very important, as in artwork the quality of design and craftsmanship and the reputation of the maker are under review. The following aspects are used to assess a good quality cut:

- Straightness of cut through and across the glass – as the cut moves depending on the speed and thickness of the glass the jet can deflect causing the cut not to be straight
- Creating a smooth kerf - generating no striations on the cut edge
- Achieving a minimum taper in the cut - keeping the cut as straight as Residual blasting on the surface of the glass
- Edge finish to the top and underside of the glass – Both surfaces of the glass can be affected during cutting. The underside can become coarse and irregular whilst the top surface can become rounded and cloudy from blasting. This is dependent on speed of the jet, thickness and the distance away from the glass.

¹ However some flash glass can be much thicker, which can be due to many reasons e.g. to the glass blower, age of glass and origin.

² ‘Linishing’ is an application used in smoothing rough edges.



Figure 1: A series of poor quality cuts. Tapering, striations towards the underside of the glass.



Figure 2: A good quality cut, no striations, taper or roughness.



Figure 3: An example of a poor quality cut visible, taper uneven of cut, striations. The taper of the jet path can be seen with glass virtually breaking away from its self. The kerf is noticeably visible. The jet appears to have struggled to get through the glass.

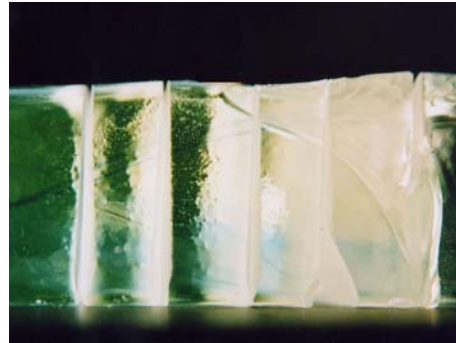


Figure 4: Examples of tapering. Profile taken from the edge of the glass. The better cut line of the five is the second on the left. The edges are smooth with little residual blasting around its edge.

Definitions of a good quality pierce

The quality of a good cut is not only about the line cut through the glass; but for shapes within the glass the pierce also has to be accurately positioned. The starting point of the cut is vital to success in producing a good cut without risk of fracture.



Figure 5: A rotating pierce with some residual blasting and uneven taper to the cutting. The pierce itself is good but the cut is poor.



Figure 6: Several pierced holes on soda-lime (float) glass with residual blasting on the surface of the glass around the pierce hole.

The following points are important when deciding on whether the pierce is good:

- Residual blasting around the pierce hole
- Any flaws or chipping around the pierce point
- How straight the pierce is and does the jet deflect or taper
- The quality of the glass underside and whether there are any flaws or abrasions

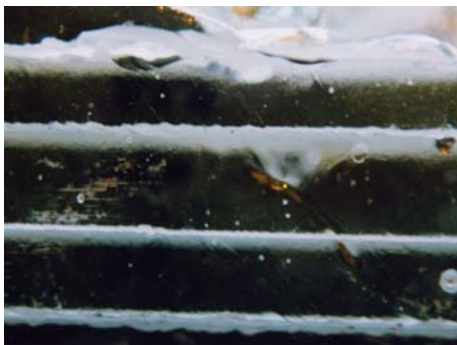


Figure 7: Detail of cuts on the underside of cast glass ingots. Note the much rougher surface.



Figure 8: Good top surface quality cut in 'flashed' glass during the curves and arcs cutting trial.

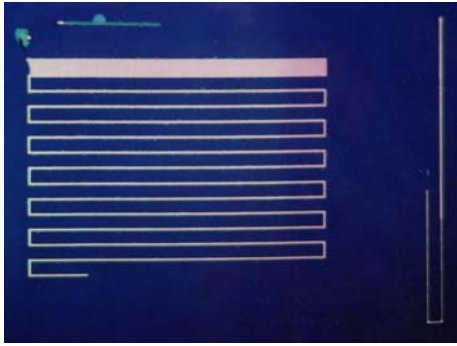


Figure 9: An example of a poor quality pierce on ‘flashed’ glass approximately 3mm thickness. In the top left hand corner of the image the glass has been pierced causing the flash blue layer of glass to chip away from the turquoise base glass. The glass has been pierced several times causing chipping and part of an area to break away.



Figure 10: An example of a good quality pierce in 30mm thick cast glass. The lower cut in the picture shows the pierce looking through the glass surface. The pierce is straight, with no residual blasting or flaving around the entry point. The abraded surface is smooth and without distortion. In the top pierce there is some noticeable residual basting on the surface of the glass.

A decision on pierce and cut-line quality is based upon professional experience. Through handling and working with the various types of glass regularly an understanding is attained of the potential that the operation can achieve. A good quality cut (*see figure10*), may be viewed differently by many, depending on the application. In this research the quality is based on comparisons of finish and how the quality relates to the finish that can be obtained manually or with cutting machines.

Rationale for the various trials

The cutting tests undertaken were to gain greater understanding of the technical issues associated with waterjet. It was to establish the creative potential and its parameters for the application of the waterjet process in glass. Each test is aimed to identify at how the jet operates for different tasks, including steepness of curve, the acuteness of angle and how the jet can achieve cut lines not available by any other processes.

- Cutting a partial line from the edge into the glass
- Cutting a line within a sheet of glass
- Sinusoidal curved lines, singular and joined together
- Curves and arcs, cutting shapes into the glass.

The cutting of a straight line within the glass is one feature that is impossible to do manually. A manual glass cutter cannot do this because the score no matter where placed in the glass the fracture line will run directly to the edge when executed. Whereas with waterjet the cut is abrading away a small line as it cuts leaving a space the width of the jet, similar to an open groove. A cut across a piece of glass from one side to the other is possible, but with waterjet a

line can be cut part of the way across easily and without complication. The tests also showed how difficult shapes can be cut no matter what the scale of application. In addition internal cuts can be easily made and are no more difficult than cutting an external shape.

4 PERSONAL METHODOLOGY

This chapter looked directly at how the researcher used the knowledge of the machine, material and processes to extend the boundaries of those three areas: material process and machine. Current practice-based methodology has always investigated technique and its application. This exploration investigates the operational methods by which a machine-made process can be applied creatively. A process has been first taught, and then by individual practice the method has been developed. This experience builds into a unique database that has been acquired through extensive handling of processes and materials that produce a distinctive body of artworks.

In the manufacture of the artworks success was based on the initial set-up stages in the production of the work. Understanding the machine's capabilities and the characteristics of the various types of glass being cut are vital. In each of the artworks the glass has different properties and in each of the applications there is a need to maintain strength and stability within the glass structures.



Figure 11: 'Fingertips' Blown glass waterjet cut. V. Cutler

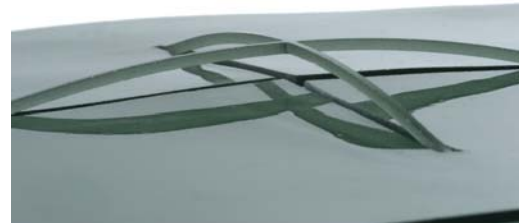


Figure 12: 'Raised crossing' waterjet glass heat manipulated through a waterjet cut steel former. V. Cutler

The role of waterjet technology within my own working practice is not based on the ability to produce multiples nor reduce production costs. In many ways it is the opposite of how the use of machines and technology are applied, especially within industry. The work is small-batch or multiple shapes that require complex programming and have to be manually overseen during cutting. The machine cannot be left unaided. It requires the operator to have an understanding of both the outcome and the programming of the work. It also contradicts the writings of David Pye on the concept of 'workmanship of risk' in using machines (Pye.1968). The waterjet work produced such as the 'Spinal' series and the 'Piercing' work increases the risk of breakage and uncertainty; yet using the waterjet is the only way these works could be created.

In my own practice the technology has instigated the idea development of the work through the understanding and manipulation of the technology. The material testing through the cutting trials has helped to inform practice and build upon new skills that in combination have resulted in artwork that is at the forefront of this technology.

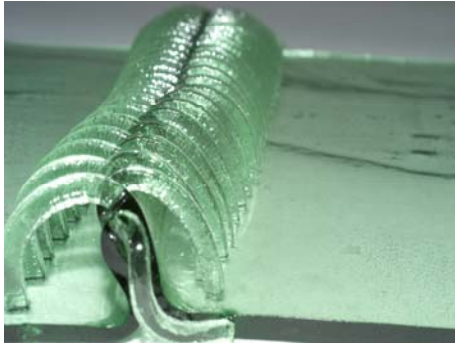


Figure 13: Autonomous and architectural artworks based on 'informed play'.

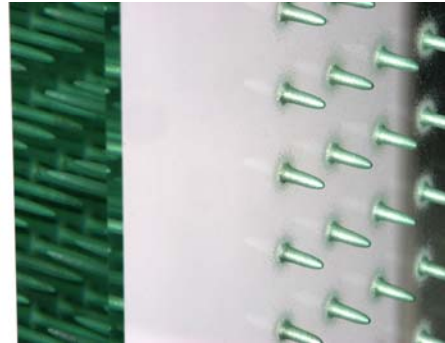


Figure 14: Figure : Artist practice and development through technique to create unique artworks.

The artworks described in this chapter have evolved in a similar fashion. More specifically their development has tended to involve three methods of practice that work alongside and inform one another:

- Making maquettes, models, and drawings
- 'Informed play' through using the waterjet machine
- Cutting trials



Figure 15: Initial drawings from maquettes.

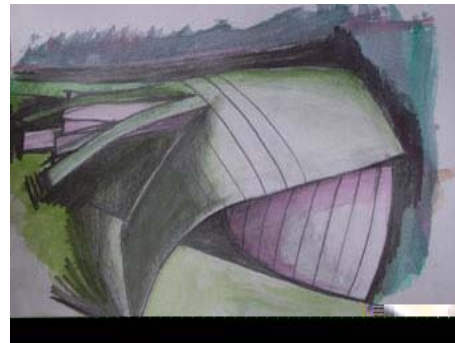


Figure 16: Initial studies from maquettes.

Each process works in parallel with another, the drawing and making of models helping to inform the practice. Alongside this, the material testing has helped initiate ideas for the development of the artworks. Through understanding the process and knowing what and how the machine cuts, the ideas are generated.



Figure17: ‘Informed play’ using waterjet cuts into glass. Placing glass into the kiln and to see how the glass can be manipulated into various different shapes. Waterjet lines into the glass could react differently to a waterjet cut shape.



Figure 18: ‘Informed play’ using waterjet cut shapes. Placing into the kiln to see how the waterjet is affected by heat and being placed at irregular angles.

The drawing and making of maquettes work alongside each other, each informing the other. They also work in parallel with ‘machine experimentation’, which informs practice through taking risks. Then my practical experimentation is informed by material testing. All three then are interlinked together, - building knowledge of the material and process, with its integration to generate an informed method of working.

Waterjet cutting is a technology that is often viewed as a tool for mass production for multiple and rapid cutting especially within its associated industries such as the aeronautical industry and mining. However the work shows that each piece of cutting is individual and non-repetitive. This may seem contradictory as repetitive shapes are used. However, for each sheet of glass there is a new machine set-up involved. This occurs in each of the case studies, where there are procedures to follow that are similar. But each project undertaken has its own parameters. Economically the work is time consuming, each piece taking many hours or days to complete - which does not utilize the concepts of this technology as was initially intended. However it does allow the work to be reproduced more easily. Once the programme has been saved it is available to be used continually, knowing that the cutting cycle is likely to be successful. The work manipulates the ability of the machine, using the repetitive nature of the machine to produce multiple shapes within a sheet of glass accurately. It relies on the skill of understanding the machine’s functions and its capabilities alongside manipulating the computerization process to meet the artist’s own criteria.

5 CASE STUDIES

This comprised for four detailed case studies working with different artists. The outcomes were primary research as a result of the artists working directly with the researcher to attain their outcomes. As a result the case studies along with personal methodology helped to inform each other in establishing guidelines of practice and parameters in which to work within.

The case studies were divided into two sections own work looking at the direct relationship and manipulation of the programming to create artwork through investigation of the material testing and the programming of the machine and associated programming.

The other section looked at how others applied the process to there work. Working directly with several artists to see have there ideas where able to be achieved from complex large files involving hand written text to smaller programs working on a variety of scales from large to quite small.

The artists worked with were the following:

- Edmund Blood- *Angel Wings*

An aesthetic and technical study to produce a wall mounted sculpture using the waterjet techniques. The role was as project coordinator offering advice on achieving a successful pair of glass wings. This case study was the only cutting carried out by a job shop. Rationale was to establish parameters of what the process could achieve. This was prior to the University of Sunderland having a machine and without the knowledge of actual hands on programming and operating of the machines personally.

- Emma Underwood- *Glass Chandelier*

The aim was to produce three waterjet glass sections matching the artists drawings for a public art commission in Sunderland. Waterjet cutting and other glass techniques were applied to achieve her aim. This was the first large project undertaken on the University machine. The project enabled further understanding of cutting parameters and the differences between cutting with Olivine and Garnet and also gains more understanding of programming and procedures. Although the project was not installed the case study did achieve the aims of this case study.

- Esther Adesigbin- *Handwritten text*

This case study was to produce three artworks all based around handwritten text.

They were as Follows:

- *I am Fine*
- *Endscript, handwritten text*
- *Scribbles*



Figure 19: Detail of scribbles, lines in areas less than 1mm thickness

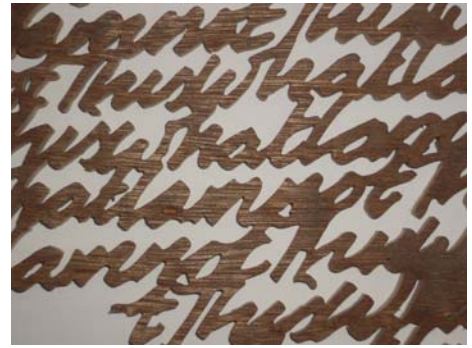


Figure 20: Detail of Handwritten text, in plywood used as protective under sheet.

All three artworks were cut using various types of sheet glass. These were the most complex studies of the four. All involved complicated programming, handling of large file, issues of scale and glass parameters to minimize the threat of fracturing. These studies enable the artists to main a more hands on approach and enable more understanding into the procedures of programming and set up of the machine alongside the parameters of the various types of glass. Utilizing what had been found within the cutting trials.

- Richard Mietner- *'My fort, My Pawn'*

This case study was part of a visiting residency for the American born artist. The time was allowed him to learn the initial parameters of generating artwork to be cut on the machine. It also allowed understanding of cutting the same image to various scales and how alterations are made to reduce the risk of fragility and stability. It also enables more understanding of facilitating, how engineer and artist can work together in making the cutting outcomes successful. This case study taught more about communication and how to understand artist requirements!



Figure 21: Image used by Richard Mietner, 'Carrot boy'



Figure 22: 'My fort my pawn' R. Mietner 2005.

6 AREAS OF FURTHER RESEARCH

The research has shown how the waterjet cutting process can be used creatively, with benefits both aesthetic and practical. It has also identified several other areas that would benefit from further investigation.

- Development of the rotating pierce into a stand-alone programme, instead of being an element of the cutting programme.
- Development of creative surface abrasion; ‘milling’
- Development of jigs for holding large and small pieces of work, with the ability to retain both cut shapes
- Development of casting with waterjet cut shapes for aesthetic effect
- Development of techniques on a smaller scale for jewellery



Figure 23: Detail of experimental milling into glass, work for Kathryn Hodgkinson 2006

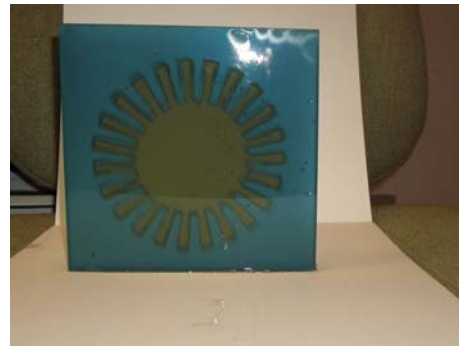


Figure 24: Detail of experimental cutting into cast glass, and recasting. V. Cutler

7 CONCLUSIONS

From a personal standpoint the idea development is becoming more machine-like in the quality of how the ideas are represented. Knowing the accuracy that the waterjet machine produces and the clarity with which the machine cuts, the designs have to convey that quality. In using the drawing programme this can be achieved; with, however, the risk of losing that spontaneous approach that comes through drawing manually. It is still drawing, but through factual figures not with the dexterity of using a pencil. Instead of rough irregular shapes the quality is linear and regimented. Although some of the case studies such as Esther Adesigbin work ‘End-script’ hand written text seem more fluid, the programming is very controlled. Although not seen as a technical guide the research gives insights as to the practical applications and the technical issues surrounding the process of the waterjet being applied creatively.



Figure 25: Manipulation of technology in my own work, 'Cartwheels' 2005 V. Cutler



Figure 26: Cutting of Esther Adesigbin work, 'I am Fine'

Within the own work and that of the case studies the research provided the evidence of how the waterjet process could be applied creatively to extend the parameters of practice, both in the material and the machine. It also showed how the initial ideas could be extended to include all areas of glass practice from architecture to hot studio glass. Some of these areas are still being explored in more current research.



Figure 27: Applying waterjet to hot studio glass



Figure 28 : Application pf waterjet cut, fused and applied to hot studio glass, by James Maskrey

As an artist using such a complex machine, not as an engineer, the logical solutions which an engineer understands are not generally within an artist's training:

- Logical and defined knowledge in the workings of the machine
- Understanding of the technical processes of the internal mechanisms of the machine
- Quick knowledge of recurrent faults and how to rectify the problem.
- Continual use and application of the machine
- Running to its capacity
- Understanding of the implications of human intervention and modifications.

All of these criteria are learnt over a period of time through working on the machine and discussions with the manufacturers. There is an element of schooling in learning the procedures and the stages of production that enable work to be cut successfully.

The standard practice in accessing such a machine for an artist would be through contacting an engineering firm that uses waterjet. The artist would have no direct involvement in the cutting and programming of their work³. This research has enabled the unique opportunity for the artist to become the engineer and understand the intricacies of the machine.

8 ACKNOWLEDGMENTS

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9 REFERENCES

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Pye, D (1968). *“The Nature and Art of Workmanship”*. London. The Herbert Press.

³ Most firms will programme any drawings to suit their computerised system and pass them to the factory floor as a job number, with little discussion as to the works outcome.