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PLASMA / WATERJET

Waterjet Evolves Into Precision Alternative

Abrasive waterjet cutting has historically been seen as a novel tool for rough cutting of materials such as steel, aluminum, titanium, Inconel® , and glass – sort of a glorified bandsaw for 2D shapes. But today's waterjet technology has advanced into new territory.

With the latest in technology offered by waterjet manufactures and coupled with one firm's technical innovations, waterjet is now entering the ultra-high tolerance 3D machining world and cutting advanced ceramics and composites in ways that compete with or replace more conventional practices in less time and for less money.

Computer algorithms that control both machine motion and waterjet cutting dynamics have pushed waterjet versatility to the forefront in modern machining practices, explains Jim Calder, president, Abrasive Waterjet & CNC Inc. (Huntington Beach, CA). In some cases, waterjet in its most sophisticated application is now a technology enabler that allows the user to manufacture in ways previously not considered. Abrasive Waterjet (AWC) is one company that is pushing the waterjet technology into this new manufacturing forefront.

3D Waterjet Cutting

Waterjet machining complex 3D surfaces with controlled stand-off (distance from nozzle to workpiece) is becoming a commonplace activity. Advances in 3-axis "Look-Ahead" positional control combined with the latest in CAD/CAM technology allows for precise cutting of non-flat components. AWC has developed this capability by writing CAM-based post processors and algorithms to complement the dynamic control software manufactured by Omax Corp. (Kent, WA). This complementary software approach combined with 3-axis (X, Y, Z) simultaneous control allows for quick setup and fast run times for waterjet cutting of complex geometries.

The key to successfully waterjetting composites is to understand the material's mechanical properties and to understand the dynamics of the cutting stream.

Key to making the technology work is to insure that the process is robust, notes Calder. AWC has incorporated commercially available off-the-shelf (COTS) software and developed easy to use post processors that generate the machine code for the Omax look-ahead processor and controller. There are a number of CAM software packages that can compliment the waterjet process. AWC has chosen its

Abrasive Waterjet & CNC is pushing waterjet technology into areas previously reserved for more traditional precision machine tools.

current milling package, Esprit from DP Technologies as a test-bed and platform for post processor development. The key to success is to allow the programmer to utilize the easy to use milling package and to subsequently post the appropriate (NC) machine code for the waterjet 3D process.

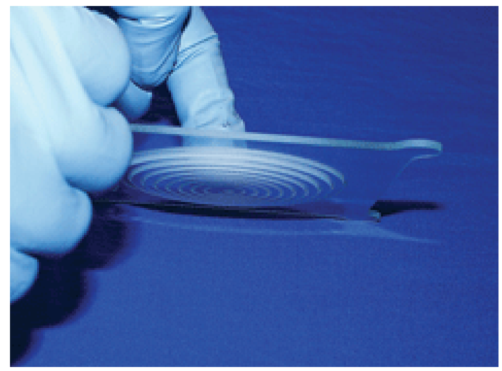
Once loaded into the Omax waterjet controller, the basic code as generated in the CAM package is then interpolated and reprocessed for look-ahead motion control. The result is a 3D machine path that is controlled dynamically to account for the non-rigid behavior of the waterjet cutting stream. Beyond posting the code and loading the file into the waterjet machine, the entire process is seamless to the operator.

From experience, Calder explains that waterjetting a 3D component can be accomplished through following these basic steps:

- Obtain or create a 3D solids or wireframe model of the component of interest.

Most designs these days are developed as solids and can be imported/exported between numerous software packages. When moving such files between different software packages, IGES, ParaSolids, and STEP formats provide the simplicity and stability needed to generate the waterjet tool path.

- Edit the 3D model in a solid modeling package. Add in lead ins/outs for starting and finishing a cutting path.



Abrasive waterjets are frequently used to cut glass. With today’s control technology, tolerances of +/-0.001" are being achieved by Abrasive Waterjet & CNC.

Packages such as Solidworks and IDEAS have proven to work well. (Though any quality modeling package will work.)

- Import the model with lead ins/outs into a CAM package.

Though AWC uses Esprit with a proprietary post processor, MasterCam beta post processors under development at AWC appear to work equally as well.

- Establish a continuous “contour” where applicable for defining the cutting path.

- Post the NC code (contour) from the CAM package.

In terms of waterjetting in 3D, AWC is utilizing the *.OMX protocol. The OMX format is used concurrently with the motorized Z-direction positional control that is now available through Omax.

- Perform final NC code edits and tool path verification in the “Omax 3D Path Editor”.

Tool-up your waterjet machine and execute the code.

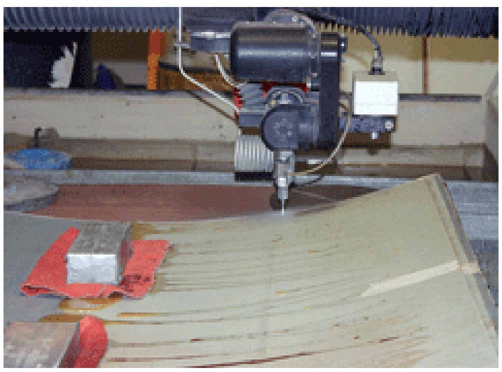
Process Evolution

Key to the evolution of the process is the refinement of the computer algorithms for positional control, says Calder. The ‘look-ahead’ control model as developed and continually being refined by Omax, combined with post processor development and refinement at AWC, result in significantly reduced man-hours to go from computer model to final component. This reduction in man-time creates an economical process that permits 3D control and machining that is utilized on a daily basis.

AWC currently waterjet cuts approximately 20% of its jobs and products using some variant of the 3D post processing and machining scheme. Typical applications benefiting from the technology include:

- Automotive products such as wheel spinners and secondary operations to wheels (rims).
- Aerospace applications such as cutting to net shape metallic and composite wing skins
- Space-based applications such as Radom trimming and complex shaped honeycomb core cutting.

Advanced Composite Materials
Waterjet cutting of advanced composite materials poses many challenges for the waterjet process. Advanced composites are typically materials with high modulus (stiffness) and moderate to high strength in the direction of the reinforcement (fibers). Common composites are typically those with graphite fiber that are consolidated as a laminate or woven structure. Those that are laminate, possess extremely low interlaminar shear and through thickness tensile strength. This low strength can create difficulties when attempting to pierce or rapid cut a composite with the waterjet process, cautions Calder.



A 3D machine path is controlled dynamically to account for the non-rigid behavior of the waterjet cutting stream.

However, by precisely controlling pressure and the introduction point of the abrasive media, it is now possible to cut virtually any composite with no delamination or back side fiber ‘blow out,’ explains the AWC president.

Delamination is a common problem when piercing through the material as opposed to starting the cut from outside the boundary of the material. When cutting inside features such as holes or cutouts, it is necessary to begin the cut within the boundaries of the composite. Most fragile composites have typically required pre-drilling a starter hole with a drill such that the abrasive stream does not pierce.

To overcome this problem, some waterjet manufactures such as Omax offer a drilling attachment to automate the pre-drilling process. However, this is time consuming and not amenable to all composite materials, adds Calder. Many composites are subject to fiber blow-out with conventional drill methods.

Key to successfully waterjetting composites is to understand the material’s mechanical properties and to understand the dynamics of the cutting stream (jet), he counsels.

Through careful control of the hydrostatic pressure that is present within the cutting stream as it enters the material, it is possible to tailor the waterjet’s cutting parameters to insure that the cutting stream does not induce prohibitive stress on the material under cut. It is the stress resulting from hydrostatic pressure that typically causes delamination and fiber blowout, he notes. Key parameters requiring proper tuning include:

- Garnet introduction point in terms of nozzle position and timing;
- the force of the cutting stream as it impacts the material. This is the amount of pressure acting upon the composite’s surface;
- waterjet stream coherence, and
- water pressure ramp rate and control.

Tuning The Jet
AWC precisely tunes its waterjets to each type of composite material to insure effective cutting rates without damage to the composite. Proper tuning is achieved through direct measurement of pressure ramp rates and resulting contact force on the workpiece. To achieve this, data is gathered through monitoring of a pressure transducer on the pressure line, monitoring a load cell attached to a steel test coupon, and timed stamped data acquisition of these signals to a PC computer.

The resulting data is reviewed, compared to a historical “Process Database”, and subsequently used to establish the correct cutting process parameters for the material of interest. Most settings that are used for overall system timing are handled in software. Unique to the software available on the Omax controller, is the ability to precisely adjust the timing of pressure, motion, and garnet parameters for the entire cutting process. In addition, AWC has added additional control to the high-pressure pump to allow for precision pressure ramp-rate control.

The results of proper tuning will yield high quality composite parts machined in a minimum of time.

Noting that every composite material behaves differently, one setup does not fit all. However, with a simple understanding of material properties and an ability to tune the waterjet, the most challenging of materials can be properly waterjet cut.

Alternative Cutting Techniques
Cutting of glass optics grade materials by waterjet is not revolutionary. However, cutting small, fragile components with high precision and accuracy while preserving the integrity of the optic’s surface is not only challenging, but also nearly impossible for many applications. For those applications with tolerances at 0.001" or larger, waterjet can be a low-cost technology and manufacturing solution, advises Calder.

Glass
Glass and its silica-based derivatives lend themselves to the waterjet process as a relatively convenient process. The behavior of the waterjet erosion process is generally very amenable to most glass materials assuming the glass is annealed or does not exhibit high residual stress. In terms of rough cutting glass to tolerances down to +/-0.005", this is typically seen as a routine process. When the limits are pushed, such as tolerances of +/-0.001", this may exceed what is typically considered for waterjet. For those willing to push the envelope, the ability to achieve this high tolerance and precision is now obtainable, maintains Calder.

There are five technical areas that if addressed properly, will allow the waterjet user to meet this high tolerance objective. The following points highlight the proper steps for high tolerance glass cutting via the waterjet process:

- Determine the dynamic settings appropriate for the glass substrate.

This can be achieved though the ‘Tuning’ of the waterjet as described in the composite machining section (above). Tailor the process to cut into the material as gently as possible…easy does it when piercing.

- Design and build rigid tooling to support the glass material.

Ensure that there is absolutely no movement. In terms of vibration, consider using visco-elastic materials to eliminate vibration and harmonics. If vibration or movement is present while waterjet cutting glass, chances are that a crack will be created and propagate.

- For ultimate tolerance and positional control, it is recommended to utilize a motion control system that resolves movement that is at least 1/5th the nominal minimum tolerance. If you have a tolerance of +/-0.001", your minimum resolution step should be 0.0004" or smaller.

- For precise taper control, utilize a gimbaled head with dynamic software support such as the Omax

Tilt-A-Jet™

- Perform high precision kerf measurements on the glass to be cut. Ultimate attention to detail is required. Measurements should be made to the resolution of the motion control system (0.0004" using the example above). Enter this value into the appropriate software data field or Boolean control box.

AWC follows these basic steps and has set its Omax controllers to resolve positional motion to 0.0002". Tooling is key for this level of waterjet cutting. In addition, protective films and ‘soft’ tooling are required to insure that the glass surface is not damaged from fixturing or from stray abrasive deflecting from the cutting surface.

Electronic Substrates
Cutting and machining of electronics wafers and substrates such as Silicon, Gallium Arsenide, and Silicon Carbide are now finding their way into the waterjet process as a viable and economic method for excising unique geometry IC devices.

Cutting of these materials requires a waterjet process that follows the same methodology employed with optical glass cutting. Added to this process is the utilization of a high magnification zoom camera for locating the artwork on an individual wafer. In most cases, it is necessary to pick up the cut lines or “Streets” with a positional accuracy of +/-0.0005" or better.

Machining of wafers by the waterjet process is in its infancy in terms of providing good economics relative to diamond slitting saws. Slitting saw methods are currently the mainstay of wafer dicing. The waterjet process is currently finding its niche for dicing geometries that are non-square or non-round. Those geometries that are complex and require multiple dicing operations can take advantage of the robust waterjet process.

The enabling technology that will allow waterjet to become more common place in the electronics community will be the development of jewel/nozzle assemblies that will result in cutting kerfs that are less than 0.006" wide.

Current street widths for electronics wafer dicing are typically no wider than 0.030" and are commonly seen as narrow as 0.005". The smallest kerf width commonly available with today’s waterjet technology is about 0.020" wide. As manufactures develop new technologies and methods to produce smaller jewel/nozzle assemblies, waterjet will grow in this industry.

The competition to waterjet in this arena is currently laser dicing. However, laser has its limits in that the laser can change the doping properties of silicon near the edges that are burned by the process. In addition, laser dicing is relatively expensive, explains Calder.

This artical was written by James C. Calder for the OMAX Corporation

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