Multi Axis "Nozzle Tilt Cutting" versus X-Y with Advanced Dynamic Software

Abrasive waterjet cutting (AWJ) technology has revolutionised the way many industries efficiently cut a wide range of materials, such as steel, stone and glass into detailed high tolerance parts.

But not all AWJ cutting equipment is the same. During the past few years much has been said about the greater advantages and benefits of multi-axis abrasive waterjet nozzle tilt cutting compensation over traditional X-Y cutting of 2 Dimensional applications. While these claims may have been partially true for traditional "simple" X-Y control, the latest sophistication of software to deal with the dynamic nature of the waterjet stream now proves this view totally misleading.

To test these claims, Jose Muñoz KMT Waterjet Systems, Kansas USA asked a number of experienced and independent Waterjet contract cutting shops to perform a series of cuts of different material thicknesses and surface qualities to compare the performance of these technologies. The overall impact of the equipment investment, maintenance, operation, and necessary support was also considered.

The process involved defining uniform test conditions and finished part surface quality requirements. An independent and knowledgeable observer, Dr. Pawan Singh of Quantum Performance Solutions Inc., accompanied Jose Muñoz during the cutting tests to verify the findings.

Following the tests, Jose Muñoz concluded that while there is a place and time for multi axis nozzle tilt cut (NTC) technology, an X-Y system with the right software can meet or exceed the performance of NTC. **"X-Y offered clear advantages over the more complex, more expensive, and more difficult to maintain multiple-axis system with nozzle tilt compensation."** - Jose Muñoz July 2005.

What follows is a summary of the tests and results achieved.

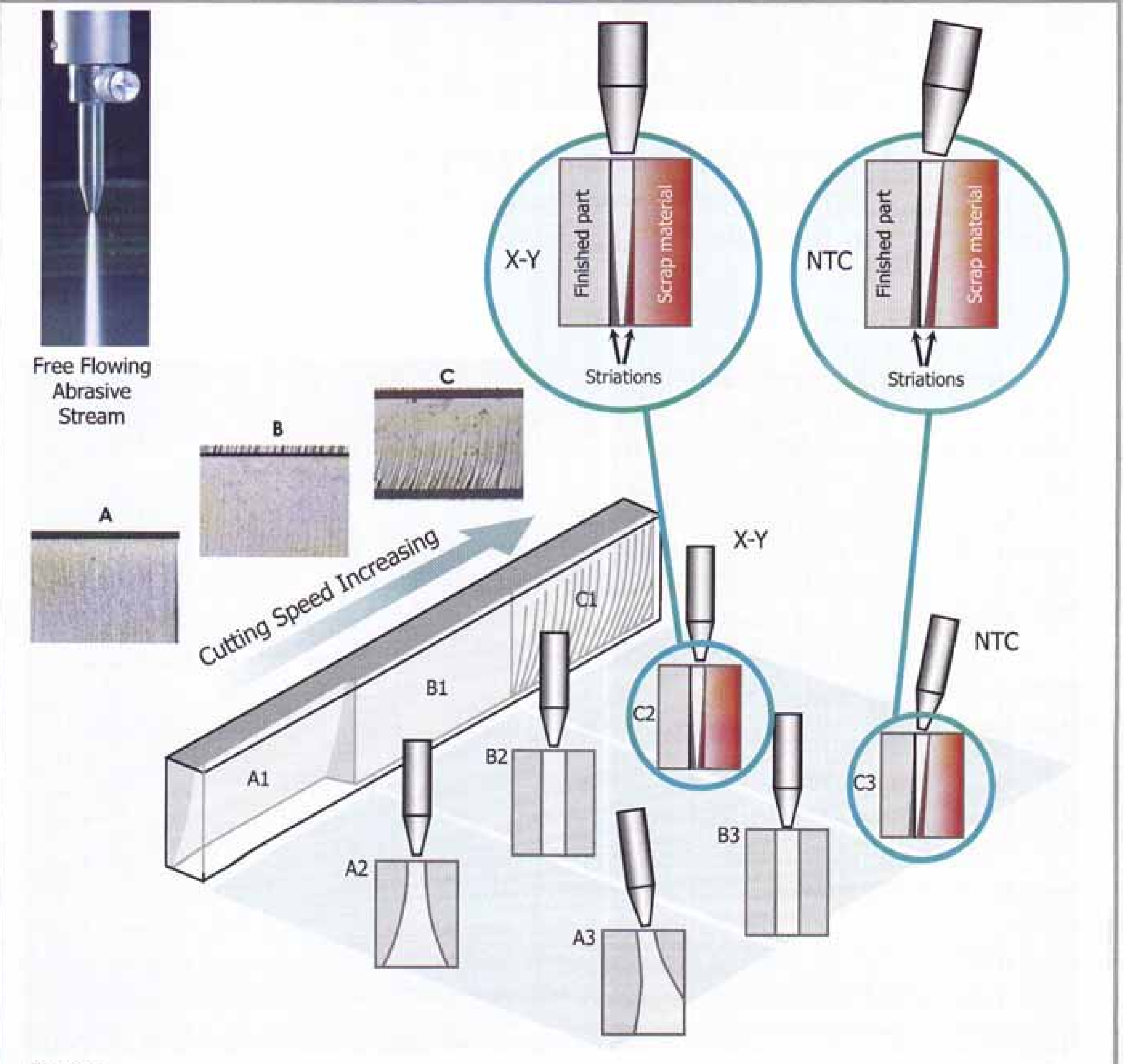


Figure 1

1.Taper reduction or elimination?

A review of the causes of taper, the non-straight surfaces cut that is created by abrasive waterjet (AWJ) cutting, provided insights into the actual impact of nozzle tilt compensation.

Figure 1 illustrates AWJ taper and striations in relation to cutting speeds

Due to the erosive nature of the process, the longer the material is in contact with the jet, the closer the taper will tend to resemble the shape of the jet. At lower cutting speeds better surface polishing also results.

Figure 1 section A illustrates that at low cutting speeds an "A" shaped taper with good surface finish will result. At higher cutting speeds the material is exposed to the jet for less time, reducing the taper. As the cutting speed is increased it reaches a 'transition' where the taper disappears altogether.

Figure 1 sections "A2" through "C2" represents a cross section of a jet normal to the material, as in X-Y cutting. "A3" through "C3", illustrate a cut cross section of a jet tilted with a multi-axis NTC to offset the taper.

A2 and A3 illustrate that since it has a good surface finish, tilting the jet will shift the taper to the desired side of the part. However, it is unnecessary as the taper is easily corrected by increasing the speed to "B", resulting in reduced cutting times without the need for tilt.

While C3 appears to reduce the taper, it is in fact imparting striations into the finished material. Only at B2 can you achieve a smooth, flat finish without taper.

Conclusion

"For all beam energy cutting technologies, such as laser, plasma and waterjet, there is an optimum cutting speed that removes or minimizes taper and delivers the best part finish properties. NTC cannot alter this tenet of abrasive waterjet cutting."

2. Better surface finish?

A review of surface finishes showed that after the transition, B1 striations (roughness) start to appear as the jet bends and drifts. Not having enough time to erode the material completely smooth. As speed increases the surface finish becomes rougher due to the forming of deeper striation (Figure 1 section C).

Among other things, surface finish created by AWJ is directly related to the time the part is in contact with the abrasive jet and the particle size of the abrasive. The longer the part is exposed to the jet (lower cutting speed) the more the polishing effect on the surface, and viceversa. Therefore the efficiency of the nozzle (a nozzle that removes material at higher cutting speeds) determines how much material is removed within a given time frame.

Independent tests in 2003, by the University of Missouri, on contract by the U.S. Department of Defense, of the six major Waterjet Cutting Head manufacturers, found the KMT Autoline™ to be the most efficient. It is capable of removing up to 400% more material, while reducing cutting costs by more than half of one of the cutting heads trialed.

In the X-Y system, the use of an efficient abrasive nozzle at or close to Figure 1 "B" conditions produced the best surface finish and eliminated the need for secondary operations. If speed is a priority and secondary operations are acceptable, then the X-Y system with a tool function offset would be favorable over NTC, as it would only require the striations be removed, resulting in faster secondary operations.

Conclusion

"The efficiency of the nozzle, and only the efficiency of the nozzle, determines the cutting speed at which striations start to form. The more efficient the nozzle, the faster it can cut without forming striations. Tilt compensation does not and cannot affect or correct rough surface finish caused by speed formed striations."

3. Better finished part geometry and accuracy at higher speeds?

The analysis looked at how different approaches to cutting intricate parts with arcs and corners affects part cutting time, geometry, and accuracy.

The tests showed that multi-axis nozzle tilt technology offers some value, up to a practical limit in cutting speed, since it corrects the undesirable jet lag in corners and arcs, with the capability to direct striations away from the part.

However, at higher cutting speeds the X-Y system speed control optimization, used in combination with the tool offset allowed moving the striations away from the part just as effectively.

Adding a high efficiency nozzle to the X-Y system consistently outperformed existing NTC systems. The X-Y system (Figure 2 center) cut the part faster while obtaining the same part tolerances and surface finish than the NTC (Figure 2 left).

The NTC cut part pictured right, shows the effect on the part while trying to exceed the cutting speed of the X-Y system.

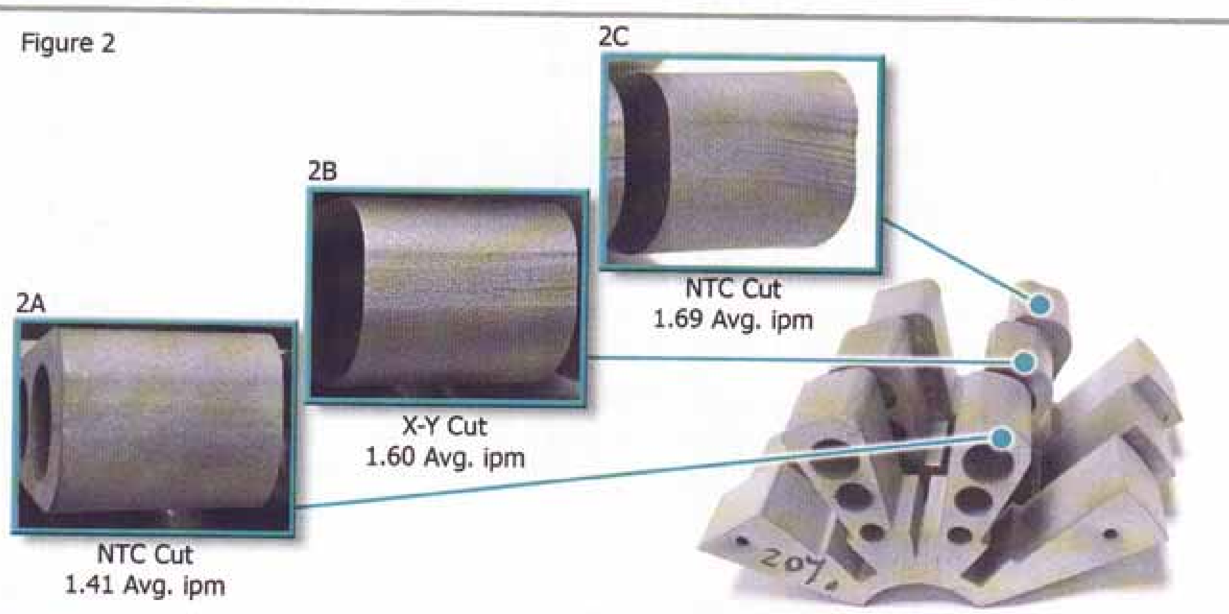
These results show that when the X-Y system is controlled by an Advanced Dynamic Waterjet cutting software that optimizes cutting speed at all points, and optimizes speed ramp up and down in corners, arcs, and transitions, the X-Y system met or exceeded the part cutting time, the part finish and tolerances obtained with the multi-axis NTC system."

Figure 2 depicts the actual parts made with a X-Y system and a NTC Multi-axis system. The X-Y system used KMT's AutolineTM efficient abrasive nozzle system and Advanced Dynamic "CutWizardTM" Software. The NTC system was Flow International's Dynamic Waterjet with Active Tolerance ControlTM and ECL abrasive nozzle system*1.

Conclusion

"The X-Y system, with an efficient abrasive nozzle system and Advanced Dynamic Software, will cut the part faster while obtaining the same part tolerances and surface finish as the multi axis NTC."

Figure 2



4. Dramatic increases in cutting speeds?

The analysis considered claims that with the present AWJ technology, and the same given operating parameters independent of the type of system, NTC cuts faster for the same finish.

Clearly, as illustrated in Figure 2, NTC cannot obtain a replica that has been cut at several speed multiples without sacrificing one, or many part finish properties such as surface finish and tolerances etc.

Conclusion

"Claims of faster cutting speeds can only be made if the claim assumes the loss of part properties are expected and understood. For a given surface finish, nozzle cutting efficiency only, and nothing else determines how fast a nozzle can cut a part."

Credentials

Jose Muñoz has been involved in all aspects of high pressure Waterjet technology design, development, and applications for more than 20 years. His contributions include many technical publications in national and international conferences, and the development of numerous technological advances in Waterjet technology. He has been granted more than 30 international patents for his inventions. For many years, Jose Muñoz led the Advanced Development Center of Ingersoll-Rand Waterjet Systems, now KMT Waterjet System, in Baxter Springs, Kansas, USA.

Dr. Pawan Singh is currently a principle in Quantum Performance Solutions, Inc., now known as PersicopeIQ, Inc. PersicopeIQ, Inc. is an information technology company providing business solutions through business consulting, application development, software development, operational performance assessments and solution evaluation. Dr. Singh has spent many years in the high pressure waterjet industry, including over 12 years in Research & Development Engineering for Ingersoll-Rand Waterjet Systems, now KMT Waterjet Systems, ABB-IR Waterjet Systems, and in his current role in contract consulting for Quantum Performance Solutions.

Footnotes:
*1 Dynamic Waterjet with Active Tolerance ControlTM is a trademark of Flow International, USA
- Tilt-A-JetTM is a trademark of Omax, USA.