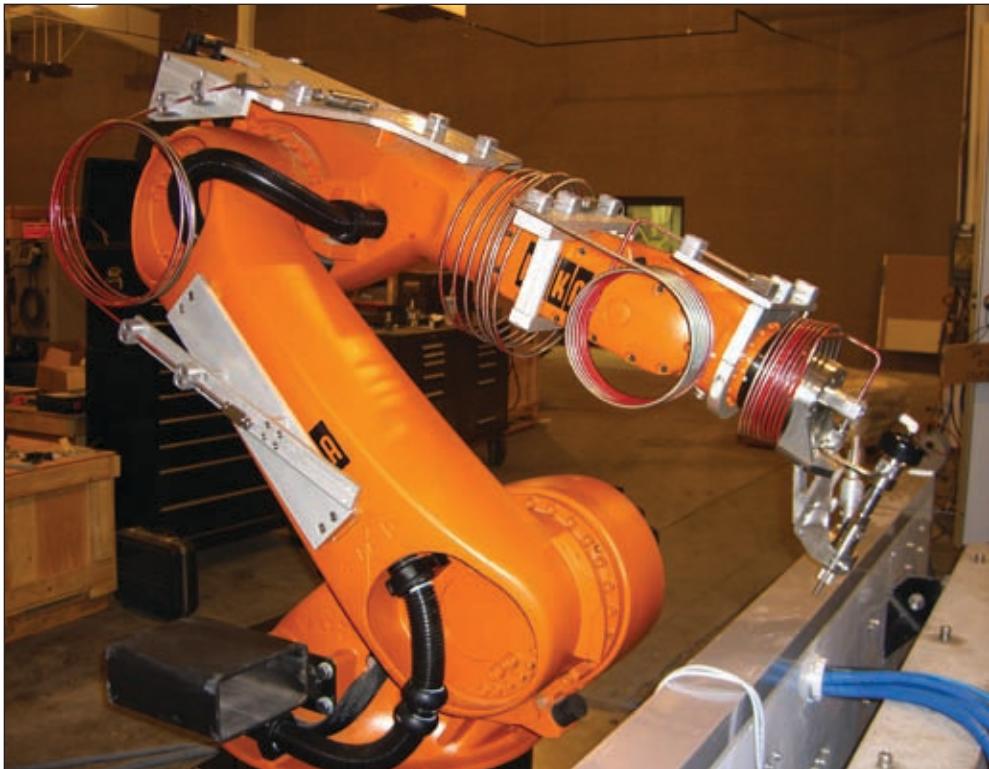


Current and Potential Robotic Abrasive Waterjet Systems

By Mohamed Hashish, Ph.D., Flow International Corporation, Kent, Washington, USA



Abrasive Water Jet (AWJ) Cutting Head.



Large Gantry for Boeing 787 Wing Trimming. Courtesy MHI.

See article on page 2.

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Current and Potential Robotic Abrasive Waterjet Systems

By Mohamed Hashish, Ph.D., Flow International Corporation, Kent, Washington, USA

ABSTRACT

5-axis gantry robots and 6-axis articulated arm robots have been used with plain waterjets for many applications, especially in the automotive industry. This paper is on extending the use of these robots to abrasive waterjets and for a much wider range of applications. The integration of the abrasive waterjet process on robotic arms has been successfully developed to address the end effector, supply of high pressure water and abrasives to the cutting head, and operational safety. Off line programming, calibration and inspection are discussed. Advanced software packages typically used in the aerospace industry have been successfully adapted. The need for enhanced accuracy performance using first article inspection results is discussed. A few case studies are presented in this paper addressing composite trimming for wing skins used in aircraft and wind turbines and for stone cutting with hybrid processes. It was found that 6-axis robot arms can easily be implemented when moderate accuracies, from 0.010 inch (0.25 mm) to 0.015 inch (0.38 mm) are specified. However, accurate calibration and first article inspection procedures were found necessary to obtain accuracies below 0.01 inch (0.25 mm). Much tighter accuracies are achieved with stiff gantry systems.

1. INTRODUCTION

Today, thousands of multi-axis robotic cells are deployed worldwide in a variety of high production environments. These include manufacturing of standard and customized components, prototype designs, and low and high volume mass production of large and medium batch sizes for OEM and aftermarket sectors. In these applica-

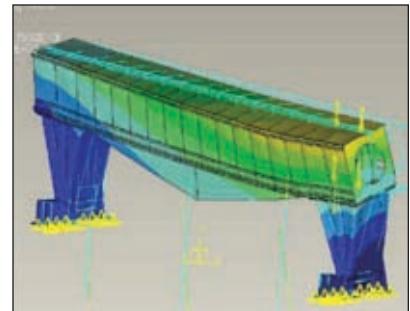
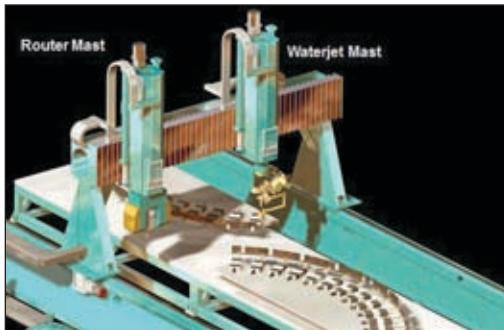


Figure 1: Gantry Structural Analysis Using Finite Element Analysis

tions, the robot accuracy and repeatability have been sufficient.

For accurate processing of workpieces, especially cutting with a beam-like cutting tool such as waterjet or abrasive waterjet (AWJ), more understanding of all aspects and process variables that affect accuracy is necessary. These variables can stack up and result in out-of-tolerance parts. These variables could be related to the manipulator, fixture, material, tool/process and the environment. The robot, for example, is a complex assembly of interconnected links, gears, gear trains, servo drives, harmonic drives and even belt drives. These result in positional and path errors which need to be compensated for. Also, recognizing the idiosyncrasies of the material such as homogeneity, shrinkage, warping, etc. will lead to minimized errors by proper compensation (1-3).

In this paper, we first address manipulators for waterjet applications, covering gantry and 6-axis robots. Then, we will address AWJ applications such as trimming, cutting and shaping using 6-axis robots with focus on composite trimming. Conclusions are listed at the end of the paper.

2. MANIPULATORS

In this section we address 5-axis gantry robots and 6-axis robotic arms

because they are the most used in multi-axis waterjet cutting.

2.1 5-Axis Gantry

The 5-axis gantry systems represented by Figure 1 are Cartesian manipulators and are designed with a relatively high degree of structural stiffness in order to achieve the required accuracy. It is typical in the design of these systems to study their structural, kinematic and dynamic behaviors using analysis software packages such as finite elements. For example, Figure 1 (right) shows the results of a finite element analysis used to determine the deflection of a gantry bridge under given loads. The analysis may also include thermal deformation and whether environmental control will be required or not based on the required part accuracy. The deflection data can be used for compensation in order to obtain more accurate results.

These gantry units are sometimes installed on a machine tool foundation and housed in a controlled environment to maximize stiffness and minimize the thermal effects. When mechanical end effectors such as routers are integrated into waterjet gantry systems, the stiffness requirement becomes the driving factor for machine construction.

(continued on page 14)

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Meet the Candidates for the WJTA-IMCA Board of Directors

JOOST BALLIEUX is the general manager for Peinemann Equipment B.V., Hoogvliet, Netherlands. He holds a degree in commercial economics and studied civil engineering. Following a tour of duty in the army on a mission with the United Nations to Bosnia as a communications specialist, Mr.

Ballieux worked for a trading company in the Middle East to implement ISO 9000 and later joined the sales force where he was introduced to Peinemann. He joined Peinemann in 1998 as a sales manager and later became the company's general manager.



Mission/Vision: In the last 15 years, I have personally dedicated most of my time to find solutions for high pressure cleaning jobs, mainly for cleaning heat exchangers, with the help of a few local Dutch cleaning contractors and other people from the field of high pressure cleaning. As we do business on a worldwide level, it is my goal to promote hands free cleaning in every country of the world to avoid (deadly) high pressure accidents that still take place very year. I believe I could bring a bit of European know-how and mentality to the WJTA-IMCA Board to make the organization more international and help to make the organization grow on a global level.

Nominated by: Kerry Petranek Siggins, Chief Executive Officer, StoneAge, Inc., Durango, Colorado.

WILLIAM BLOOM has been the vice president of business development at VLN Advanced Technologies, Inc., in Ottawa, Ontario, Canada, since 2000. His expertise has been utilized in the commercialization of the Ultrasonic Forced Pulsed Water Jet. Mr. Bloom's communications skills and ability to build relationships in industry have helped to produce opportunities in the aerospace, automotive, nuclear, and other industries.



Mission/Vision: As a member of the WJTA-IMCA and having attended conferences over the past 13 years, I believe my mission and vision for the WJTA-IMCA is to build awareness of the safety practices within industry, be a steward within the industry for the environment, engaging the membership in meaningful educational

discussions and collaborations, as well as help to grow the membership so that the association becomes a strong voice for small and large corporations within the industry.

Nominated by: Mohan Vijay, Ph.D., President, VLN Advanced Technologies, Inc., Ottawa, Ontario, Canada.

FRED CLARK is the CEO and corporate secretary for IVS Hydro, Inc. As the only remaining original stockholder in the company, which was founded in 1972 by his father, himself, and two other co-founders, he has dedicated over 40 years to the growth of the company in the areas of waterblasting and vacuum truck services. Being a 1976 graduate of the West Virginia University School of Law and a practicing attorney could not even keep him away from the business created in his own back yard. From performing work as a waterblaster himself during the 1970s to working his way through the business overseeing operations, accounts, accounts payable and receivable, safety, and eventually becoming CEO in 2000, Mr. Clark has first-hand knowledge of the industry, its practices, its growth, and most importantly, its potential. IVS Hydro, Inc. will celebrate its 41st anniversary in June 2013 and has become a national multi-division/multi-million dollar corporation within the industry. With divisions in industrial services, hydrodemolition services, environmental services, silo and bulk storage services, dredge and dewatering services, and most recently adding commercial diving services, Mr. Clark remains committed to the advancement of waterblasting and this industry throughout the 21st century.



Mission/Vision: I wish to see the continued growth of our industry and expansion into broader areas of industrial, manufacturing, utilities, and mainstream government work. Allowing our industry to grow with the advancement of technology yet still maintaining the basic core values of safety in waterblasting is a key component to the growth and recognition of the WJTA-IMCA as a national and international leader in safety, best practices, and product development. I believe the continued involvement and coexistence of contractors, manufacturers of industry products, vendors who provide the necessary accessories

(continued on page 5)

Meet the Candidates for the WJTA-IMCA Board of Directors, from page 4

such as PPE, and the end users who utilize our services, is a key to the continued growth and success of the WJTA-IMCA. Through show promotion and networking, I will continue to work hard to advance the WJTA-IMCA within our own industry and beyond. I look forward to serving on the Board of Directors with other leaders in our industry to ensure its continued success. With a mixture of "blue-collar" know-how and "board room" savvy, I feel I can be of benefit to the WJTA-IMCA and its members.

Nominated by: Scott Coleman, Safety, Health & Enviro Director, IVS Hydro, Inc., Institute, West Virginia.

KAY DOHENY is the owner of Jack Doheny Supplies, Inc., Northville, Michigan. After receiving her bachelor's degree in business marketing, she spent some time in Arizona selling industrial paper and packaging products. In 1985, Ms. Doheny moved back to Michigan and returned to work at the family business, Jack Doheny Supplies, Inc. Founded by her father, Jack Doheny Supplies has been in operation in excess of 50 years. Jack Doheny Supplies is dedicated solely to providing solutions for industrial and municipal cleaning equipment and maintenance of sewer systems. Now, as owner of the business, Ms. Doheny remains committed to moving this industry forward and to its related safety issues.



goals, and timeline for implementation. We specifically identified our core membership, discussed their needs and determined how best to service them. We also discussed how to promote and strengthen our overall membership. I welcome this opportunity to be a consistent voice in making our plan a success.

Nominated by: Kerry Petranek Siggins, Chief Executive Officer, StoneAge, Inc., Durango, Colorado.

BILL GAFF is vice president of sales and marketing for Vacuum Truck Rentals and Vacuum Truck Sales and Service, both headquartered in Jackson, Mississippi. Mr. Gaff has worked in the environmental industry for over 30 years starting out as a service technician at then Peabody Myers (Vactor Manufacturing and a subsidiary of Federal Signal). Mr. Gaff has held various management positions, including



(continued on page 6)



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Meet the Candidates for the WJTA-IMCA Board of Directors, from page 5

president of The Air and Water Group of Federal Signal, which included Vactor Manufacturing, Guzzler, and Jetstream. He also held the positions of president of Vactor Manufacturing, vice president of sales and marketing, vice president of industrial products and vice president of strategic sales. Mr. Gaff has a bachelor's degree in finance and business administration from Illinois State University and graduated from the University of Michigan Executive Program. He currently serves on the WJTA-IMCA Board of Directors as chairman of the board.

Mission/Vision: In my two terms on the WJTA-IMCA Board, we have made some significant advances in expanding the services we offer our membership to include the industrial vacuuming industry as well as the water blasting industry. I see the WJTA-IMCA becoming even more progressive in defining and sharing industry standards and best practices in the water blasting and industrial vacuum industries. I also see this organization's role expanding its scope to additional adjacent industries in which WJTA-IMCA members also do business. This defining and sharing of best practices will help improve the safety of its members' industries as well as reduce the operating costs, such as legal, insurance, and training. The WJTA-IMCA can also provide operational, training, and safety guidelines for smaller companies who do not have the size or staff to ensure that their training and safety practices allow their workers to operate in the safest work environment possible. It has been my honor to have served as the chairman of the board for the past two terms. I believe the WJTA-IMCA is poised to continue to provide value to its members and the industries it serves, and I would be honored to continue as a member of the board.

Nominated by: Gary Noto, Chief Executive Officer, Aquilex HydroChem, Deer Park, Texas.

MOHAMED HASHISH, Ph.D., is a founding member of the WJTA-IMCA. He is a senior vice president of technology at Flow International Corporation, Seattle, Washington, where he has been working since 1979. In 1980, Dr. Hashish invented the abrasive waterjet technology, revolutionizing the field of waterjet cutting. He is also honored as an affiliate professor at the University of Washington Mechanical Engineering Department. Dr. Hashish holds about 35 patents in the areas of jet cutting,



surface preparation, and high pressure technology. He has published more than 320 papers in many journals and conference proceedings. He edited several proceedings for the WJTA-IMCA and the American Society of Mechanical Engineers (ASME). He was also selected for the first technology award from WJTA and then awarded the pioneer and service awards. Dr. Hashish currently serves on the WJTA-IMCA Board of Directors, is a fellow of the ASME, and has several professional activities, such as being a reviewer for the National Science Foundation (NSF) and several journals.

Mission/Vision: My vision for the WJTA-IMCA is to become the world leading organization in promoting and spreading the waterjet technology, safety, training, and best practices to all who are involved in this industry and continue to provide the greatest value to all members. My mission on the board is to ensure that the WJTA-IMCA is providing the latest information on technology, new applications, education, training, safety, and best practices through publications, videos, boot camps, conferences, exhibits, and the web.

Nominated by: Mohan Vijay, Ph.D., President, VLN Advanced Technologies, Inc., Ottawa, Ontario, Canada.

BILL KRUPOWICZ is a vice president of Federal Signal's Environmental Solutions Group (ESG). He is the general manager of Jetstream of Houston, LLP, and the vice president of industrial sales for ESG. Mr. Krupowicz has been with Federal Signal for 13 years. His current role spans Jetstream



waterblasters, Guzzler industrial air movers, and Vactor hydroexcavators. Mr. Krupowicz's industry experiences span the functions of engineering, materials management, finance, marketing, global sales, and general management. Over the past 29 years, he has worked in the aerospace, construction equipment, papermaking equipment, and environmental solutions industries with such companies as Hughes Aircraft Company, Caterpillar, Beloit Corporation, and Federal Signal. Mr. Krupowicz holds a BS degree in mechanical engineering and an MBA, both from the University of Illinois.

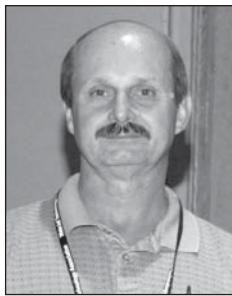
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Meet the Candidates for the WJTA-IMCA Board of Directors, from page 6

Mission/Vision: The WJTA-IMCA needs to push for broader awareness and usage of UHP water power and hi-vac air movement in industries far broader than the greater industrial cleaning and remediation segments. We should strive to expand our membership from other diverse industries, such as oil and gas, road construction, ship building and servicing, and utility construction and servicing. The WJTA-IMCA should be a growth engine for our industry.

Nominated by: Anthony W. Fuller, Director of Industrial Sales, Federal Signal, Leeds, Alabama.

BILL MCCLISTER is the vice president of equipment and technology for Veolia ES Industrial Services, Inc., where he has been employed for 32 years. Mr. McClister is a former WJTA-IMCA Board member and played a significant role in attracting the industrial vacuuming industry to the WJTA-IMCA.



Mission/Vision: I believe that I can assist the WJTA-IMCA to continue to grow its leadership role in setting safety and operational standards for the waterjet cleaning and industrial vacuuming industries. These standards must be adaptive to advancing technologies and environmental concerns. I hope to increase the value that the WJTA-IMCA provides to all segments of its membership.

Nominated by: Bill Gaff, Vice President of Sales and Marketing, Vacuum Truck Rentals/Vacuum Truck Sales and Service, Jackson, Mississippi.

GARY NOTO's career in waterjetting and the industrial vacuum business began in 1978 as an administrator and technician for Hydro-Services, Inc. in Baton Rouge, Louisiana. He served as the New Orleans and later southeast region operations manager. Mr. Noto performed the first automated rotary tube lancing job for DuPont Pontchartrain in a hazardous environment. He developed business relationships, including contract negotiations, with



numerous local and national refineries and petrochemical plants. Upon the company being acquired by HydroChem, Mr. Noto served as company safety director, manufacturing support services, region manager, and finally company president and chief operations officer. His career with Hydro-Services/HydroChem spanned 24 years, during which the company's revenues grew from \$10 million to \$225 million per year. Mr. Noto's accomplishments include team involvement in numerous safety and technology innovations. He spent nine years employed with Veolia ES Industrial Services, Inc., as executive vice president and chief operations officer, and has recently rejoined HydroChem as chief executive officer. Mr. Noto's focus and accomplishments continue in the area of safety and technology as well as business development.

Mission/Vision: My mission as a WJTA-IMCA Board member will be to continue the current growth cycle and evolution of the WJTA-IMCA. The current membership body is mostly comprised of those representing the research and development sector, equipment, tooling, and cleaning

(continued on page 8)

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Meet the Candidates for the WJTA-IMCA Board of Directors, from page 7

contractors. The group that is missing is the end users – the chemical plants, refineries, steel mills, power plants, and other industries that require the use of waterjets and vacuum equipment in their facilities on a daily basis. The WJTA-IMCA, as the safety and best practices standard bearer for the waterjetting and industrial vacuuming industry, has significant value to these end users. As a WJTA-IMCA Board member, I will use the relationships built over my 35 years of service to our industry to draw this group to the WJTA-IMCA, as well as continue to develop better ways we can service our existing members.

Nominated by: B.T. Steadman, Vacuum Truck Rentals, LLC, Richland, Mississippi.

GEORGE A. SAVANICK, Ph.D., is a founding member of WJTA-IMCA. He presently serves as the president, chairman of the Waterjetting Safety Committee, and the editor of *Jet News*. He is a Pioneer Award winner and a recipient of the Service Award. He is especially interested in industrial safety and in promoting communication among members of WJTA-IMCA. He desires to foster a WJTA-IMCA wherein all people interested in fluid jet technology and allied technologies will feel welcome and prosper.



Mission/Vision: My vision for WJTA-IMCA is that the membership will be composed of people interested in all aspects of fluid jet technology and that there will be an open exchange of information among members. I foresee an organization wherein members learn from each other and thereby advance fluid jet technology. My fondest hope for the future is that industrial waterjet and vacuuming accidents will cease to occur.

Nominated by: Grzegorz "Greg" J. Galecki, Ph.D., Associate Professor of Mining Engineering, Missouri Science & Technology, Rolla, Missouri.

An official ballot listing the eligible nominees and a brief biographical sketch for each individual will be forwarded by mail on **June 10, 2013**, to all eligible voting members of the WJTA-IMCA. Signed and executed ballots must be forwarded to the Association's office for tallying no later than **July 15, 2013**.

TRYAN STUTES is the founder and president/CEO of Stutes Enterprise Systems, Inc., a leading waterjetting equipment rental and supply company in the Texas and Louisiana area established in late-1997. Mr. Stutes has been in the industrial cleaning business for over twenty years. During this time, he learned the value of solid work ethics and what the word "service" really means. Since that time, using his experience from the field, he played a key role in the success of several industrial rental companies achieving top sales. Mr. Stutes started out with two rental units, one truck, a modest customer base, and big ambition. Stutes has become a leader in the industrial waterjetting equipment rental and supply industry, setting high standards for quality equipment and superior service to meet the needs of their customers. Mr. Stutes has worked with various manufacturers of waterjetting pumps, accessories, and tools to help improve their products making them more productive, safer, and more user friendly for field personnel. Stutes has multiple locations along the Gulf Coast and is a multimillion dollar company with plans to expand product lines and increase inventory and locations.



Mission/Vision: My mission is to promote the WJTA-IMCA and continue to seek out new members, not only from the petrochemical industrial markets, but from all other types of industries; to maintain existing members by providing outstanding customer service; to continue to improve, promote and encourage the safety practice procedures; to work with manufacturers to develop cutting edge technology, equipment, and products to increase safety and productivity; and to aid in the education process helping the end user understand that waterjetting is a specialized trade, an art, a skill and should be treated as such. As a board member, I will utilize the entrepreneur spirit as well as my years of technical experience to help accomplish the goals of the WJTA-IMCA. The WJTA-IMCA should be the vehicle to bridge manufacturers, rental companies, industrial service companies, and the end user together.

Nominated by: Luis Garcia, President, CSM Supply, La Porte, Texas.

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NLB Surface Prep Equipment Helps BNY Mellon Center Earn Project of the Year Award

A surface preparation project that overcame many challenges with the help of NLB waterjetting equipment was honored February 20th by the Engineers' Society of Western Pennsylvania as the Remediation Engineering Project of the Year.

A variety of issues complicated the BNY Mellon Center project in downtown Pittsburgh. First was the surface itself: the building is covered with 30-foot painted steel panels that could not be removed and had to be stripped and repainted in place. Other complications included continuous work on a 54-story building while protecting the continuous traffic below and minimizing noise and disruption for employees working in the building and guests at the hotel across the street.

Contractor Burchick Construction of Pittsburgh chose to remove the rust and old coatings with ultra-high-pressure (UHP) waterjetting equipment from NLB Corp., which works quickly and leaves an excellent surface for recoating without any abrasive media that could harm passing pedestrians, vehicles or the environment.

Burchick personnel used custom HydroPrep™ waterjetting tools from NLB, with three NLB Series 40225E pump units to supply the ultra-high pressure (40,000 psi) water. These electric units were set up in the building's garage to minimize noise, with the water fed up through the building and recovered after the jetting operation to be filtered and used again.

Some of the waterjetting was done with hand lances and some with semi-automated VertaJet™ SRT-6-LT units, which remove corrosion and coatings with patented rotating waterjets in a six-inch path. These units feature

vacuum recovery that eliminates the need for containment and are typically handheld with vacuum attachment to the surface to reduce strain on the operator. NLB also supplied custom high-pressure waterjetting tools that were mounted in custom frames fitted to the building facade.

For more information visit www.nlbcorp.com or call (248)624-5555.



Surface prep on the 30-foot panels covering the BNY Mellon Center was done in place with VertaJet units from NLB.

Jetting Away the Impurities

Hughes Pumps supplied a specially designed and manufactured remote control waterjetting system to Wyman-Gordon's UK plant in Lincoln where the company specializes in the manufacture of complex forged metal components and products for major industrial, power generation and aerospace applications.

During the forging process scale and impurities develop on the forged metal's surface and have to be removed to avoid their being hammered into the billet. Waterjetting is an ideal process for removing this scale.

The company had previously used a pump-set operating at 1000 bar (14,500 psi) to drive a single rotating nozzle, but this covered only one fifth of the surface



A typical forging application.

area of a 200 mm (8-inch) diameter billet, requiring the red hot billet to be indexed and manually passed under the waterjet five times to de-scale its total surface.

Wyman-Gordon asked Hughes Pumps to design a system that would have five times the capacity of the existing system, so enabling the five rotating nozzles, fixed in a spray ring, to de-scale the forged billet in a single pass and increase productivity.

(continued on page 32)



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Michael Waltrip Racing, Jet Edge Renew Technical Partnership

Michael Waltrip Racing (MWR) and Jet Edge, Inc. are renewing their longstanding technical partnership. MWR and Jet Edge also announced that MWR is installing a second Jet Edge waterjet cutting system at its fabrication shop in Cornelius, NC.

Brian Vickers drove the #55 Jet Edge Toyota Camry in the Virginia 500 April 7 at Martinsville Speedway.

MWR uses its Jet Edge precision waterjet cutting system to cut more than 1,000 parts for each of its NASCAR Sprint Cup cars. It builds about 56 cars per year, including the #55 Aaron's Dream Machine Toyota Camry driven by Michael Waltrip, Mark Martin and Brian Vickers, the #56 NAPA Auto Parts Toyota Camry driven by Martin Truex Jr., and the #15 5-hour ENERGY Toyota Camry driven by Clint Bowyer.

For its second waterjet machine, MWR has selected a Mid Rail Gantry system equipped with Jet Edge's latest Permalign® EDGE taper control and bevel cutting technology. The system features IGEMS CAD/CAM/NEST-ING software and is powered by a 60,000 psi 100 hp Jet Edge intensifier pump. This new multi-axis waterjet system will complement MWR's existing 3-axis 90,000 psi 100 hp High Rail Gantry system, which was installed in 2008.

"Our business is all about speed," said Michael Waltrip. "We have to get design improvements to the racetrack as fast as possible to be competitive, and that's going to be more important than ever this year with NASCAR's mass rule changes. Our first Jet Edge helped us get new parts to the race-track two weeks faster and made us a force to be reckoned with. Just think what we'll be able to do with two Jet Edges!"

Jet Edge President Jude Lague said Jet Edge is thrilled to continue its relationship with MWR.

"Our partnership with MWR has exceeded our wildest expectations," Lague said. "They have been a powerful endorsement of our capabilities and we're proud to be associated with such a first-class organization. We're really excited that Brian Vickers is racing for us again this year. He had a great run at Loudon and we're looking forward to Martinsville."

For more information about Jet Edge, visit www.jetedge.com, call



MWR cuts more than 1,000 parts for each of its racecars with a Jet Edge waterjet cutting system.

1-800-JET-EDGE (538-3343) or e-mail sales@jetedge.com.

Typhoon™ Rotating Nozzles Clean Small Pipes

Typhoon™ 10 self-rotating nozzles from NLB Corp. maximize the power of high-pressure waterjets to clean small pipes (diameters of 5/8-inch or 3/4-inch). Designed to produce the rotating action from the nozzle instead of the barrel, they focus the force of the waterjets up front where it is most effective.



The Typhoon 10 series features four models, with pressures and flows to suit user needs:

- RPN1510 – up to 15,000 psi (1,035 bar) at up to 10 gpm (38 lpm)
- RPN2410 – up to 24,000 psi (1,680 bar) at up to 10 gpm (38 lpm)
- RPN1520 – up to 15,000 psi (1,035 bar) at up to 20 gpm (76 lpm)
- RPN2020 – up to 20,000 psi (1,400 bar) at up to 20 gpm (76 lpm)

All models are made of high-grade stainless steel for durability and rotate at 7,000 rpm. They feature the latest NLB seal design to reduce leakage and can be ordered with four jets for polishing, or with five jets for cleaning and cutting.

Two more Typhoon nozzles are available for larger pipes: the Typhoon 20 for diameters of 6 to 10 inches and the Typhoon 60 for diameters from 11 to 50 inches. NLB also offers a wide range of non-rotating pipe and tube cleaning nozzles with a variety of operating pressures, threads (left-hand or right-hand) and drill patterns.

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Contractor Develops Clamp to Improve Vacuum Truck Grounding Issue

Vacuuming in areas with combustible dust presents a safety hazard requiring careful attention to electrical safety. Jet Blast Industrial Services found that when vacuum pipe and hose connectors became soiled or rusted, electrical resistances above the 10 ohms sometimes occurred. The OSHA – Combustible Dust National Emphasis Program CPL 03-00-008 calls for proper grounding and bonding. To assist us in that knowledge we participated in training from FS Solutions by instructor Gary Tooth who explains that less than 10 ohms between connections is the goal.

To solve this problem, Jet Blast created a clamp to enhance continuity. The continuity clamp takes a universal clamp with $\frac{1}{4}$ -inch thick and $\frac{3}{4}$ -inch



wide stainless steel welded across the top. The tips were machined to a point to provide penetration through build up on the outside of the pipe or hose and the wing-nut was button welded. Work on the clamp was done by a local machine shop.

Electrical resistance was tested by duct taping the male end of pipe and sliding it into the female end. This



showed an open circuit when testing with a multi-meter, but the electrical resistance dropped to nearly zero when the continuity clamp was applied.

Submitted by Jet Blast Industrial Services. For more information contact Don Morningstar, Director of Purchasing & Safety, Jet Blast Industrial Services: (410) 636-0730 or email don@jetblast.net.

Current and Potential Robotic Abrasive Waterjet Systems, from page 2



Figure 2: Large Gantry for Boeing 787 Wing Trimming. (Courtesy MHI)

Helical rack and precision gear boxes and closed loop control systems contribute to smooth motion and high accuracy. Before using these machines, the linear axes are compensated using laser interferometers. Linear encoder scales are also used to increase the accuracy on large-scale systems. Figure 2 shows a picture of a typical 50 m long hybrid waterjet-router gantry system used for trimming wing skins for the Boeing 787 (4).

2.2 6-Axis Robotic Arms

6-axis articulated arm robots have been used in a very wide range of

industries such as automotive, electronics and entertainment due to their flexibility, relatively low cost and reduced footprint. These robotic arms can also be mounted in a variety of ways based on the application such as floor mount, ceiling mount, gantry mount, wall mount, etc. as shown in Figure 3.

Although highly repeatable, robots are not accurate until they are “mastered,” i.e., compensated. They are typically manually taught by eye from a teach pendant, Figure 4, using a “point-to-point” format. The programmer may choose to use a custom pointer as the simulated Tool Center Point (TCP) or a peripheral laser pointing device aimed at the target zone, or they may simply guess and cut a part, measure



Figure 3: 6 Axis Robots, Floor, Ceiling, and Wall Mounted



Figure 4: Typical Hand Held Teach Pendant Hardware for Point-to Point Teaching

the deviations, and correct it with another pass and so on.

(continued on page 24)

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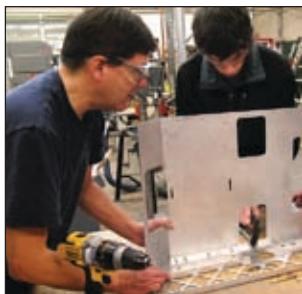
OMAX® Corporation received the inaugural *Inspire Award* from the Pacific Northwest Aerospace Alliance (PNAA) for its leadership and creativity in cultivating student interest in future aerospace manufacturing careers.

Of the company's many educational outreach initiatives, one main focus has long been to provide youth with easy access to the manufacturing industry. From secondary education and high school programs to extensive higher education internship opportunities, OMAX facilitates student participation in pursuing high-skill, high-paying manufacturing jobs.

"Manufacturing is a viable and growing industry that makes for a lucrative career path, yet shops ev-

erywhere continue to find it increasingly difficult to find skilled workers," said Dr. John Cheung, chairman and CEO

of OMAX Corporation. "One reason for this gap is people's misconception that manufacturing facilities are dark, dirty and low-tech places. But, nothing could be further from the truth. Today's manufacturing environments are clean, safe and extremely high-tech. Therefore, OMAX takes pride in working with students of all ages and encouraging them to be the next gen-



Mentoring Aviation High School's First Robotics Team.

eration of manufacturing and technology leaders."

As part of its outreach efforts, OMAX serves as an ongoing manufacturing mentor and supporter of Aviation High School's Skunkworks Robotics and Highline High Tekerz Robotics teams. During a six-week build season, OMAX engineers work closely with students and teachers in the production of advanced robot components. Teams are able to design, fabricate and test all robot components using OMAX's advanced abrasive waterjet technology.

The company's educational commitments also extend into higher education. For more than five years,

(continued on page 30)

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September

George R. Brown Convention Center

Preliminary Schedule of Events

Monday, September 9, 2013

- 8:00 a.m.-4:30 p.m.
Pre-conference Workshop – Basics and Beyond
- 4:30 p.m.-5:30 p.m.
WJTA-IMCA General Membership Meeting

Tuesday, September 10, 2013

- 8:00 a.m.-10:30 a.m.
Live Demonstrations
- 10:30 a.m.-5:00 p.m.
Exhibit Hall Open
- Time TBA
Indoor Robotics Demonstrations
- 10:30 a.m.-5:00 p.m.
Boot Camp Sessions
- 10:30 a.m.-5:00 p.m.
Emerging Technology, New Applications - Papers
- 5:00 p.m.-7:00 p.m.
Industry Appreciation Reception and Awards Ceremony

Wednesday, September 11, 2013

- 8:00 a.m.-10:30 a.m.
Live Demonstrations
- 10:30 a.m.-1:00 p.m.
Exhibit Hall Open
- Time TBA
Indoor Robotics Demonstrations
- 10:30 a.m.-1:30 p.m.
Boot Camp Sessions
- 10:30 a.m.-1:00 p.m.
Emerging Technology, New Applications - Papers

■ Exhibits and Live Demos

■ One-day Workshop, Water Technology - Basics and

■ Boot Camp Seminars

■ Emerging Technology, New Applications - Paper Pre



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- CSM Supply
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- D&S Professional Services
- Diesse Rubber Hoses S.p.A.
- Dragon Products, Ltd.
- FS Solutions
- Fruitland Manufacturing
- GHX Industrial, LLC
- GapVax, Inc.
- Gardner Denver Water Jetting Systems, Inc.
- General Pump, Inc.
- Giant Industries, Inc.
- Global Vacuum Systems, Inc.
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- Hammelmann Corp.
- High Pressure Equipment Co.
- HoldTight Solutions, Inc.
- Jack Doheny Companies, Inc.
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Boot Camp Seminars

Tuesday, September 10, 2013

Hydroexcavation in the Oil and Gas Industry

Neil McLean, Hydroexcavation Consulting Unlimited, will discuss hydroexcavation applications for contractors serving the oil and gas industry. Mr. McLean will share tips on ways to increase the productivity of your hydroexcavation unit and operate in a safe and efficient manner.

Refractory Removal by High Pressure Waterjets

Doug Wright, Director of Research and Development, StoneAge, Inc., will discuss the benefits of refractory removal by high pressure waterjet and the most effective operating parameters for refractory removal. Mr. Wright will review typical applications and teach you how to estimate rates of refractory removal.

Grounding and Bonding Vacuum Trucks

Mike O'Brien, Product Manager, Newson Gale, will give you an in-depth look at how vacuum trucks can be grounded and protected from electrostatic ignition hazards. Learn why static electricity presents a potential source of ignition in combustible atmospheres, what grounding is, and why it is so important to do it correctly.

The Basics of Efficient Manual Waterblast Use

Gary W. Toothe, CET, Training Manager, FS Solutions, will review how to use the horsepower formula to solve questions about horsepower, flow, and pressure. Mr. Toothe will show you how to calculate the differences between pump pressures and actual cleaning pressures and how to minimize pressure losses in waterblast systems.

Nozzle Selection

Bill Shires, Director of Marketing and Business Development, StoneAge, Inc., will present an overview on understanding and controlling pressure loss, and he will demonstrate the importance of jet quality across all pressure ranges. Mr. Shires will evaluate stand-off distances, material jet-ability, and other aspects of nozzle selection.

Overcoming the Barriers to Hands-Free Hydroblasting

Tyler Bargas, Maintenance Contract Administrator, The Dow Chemical Company, will discuss how the Louisiana operations of The Dow Chemical Company have reduced the potential for injuries through implementation of hands-free cleaning requirements. Learn more about required training for hydroblasting technicians and continued compliance with Dow's global hydroblasting safety standard.

Waterblasting Safety – Everyone's Responsibility

Edward Twaddell Jr., Application Engineer, TurtleSkin WaterArmor by Warwick, will discuss the dangers involved in waterjetting work and how to avoid waterjet accidents. Mr. Twaddell will address equipment and checks, procedures, and leadership responsibilities.

High Pressure Hydroblasting Hose Failure and Life Cycle Analysis

Rick Pitman, CSP, Director, PSC Industrial Services' Environment, Health, and Safety Technology (EHST), will discuss why high pressure hose failures are a leading cause of loss in the hydroblasting industry. No widely known quantifiable data exist regarding life span, run time, and failure rates. PSC began the first comprehensive study of such data in January 2012 and Mr. Pitman will share the first year's worth of data. Such data should help contribute to a greater understanding of hose life expectancy and methods to more safely handle and utilize high pressure hoses in hydroblasting operations.



Industrial Vacuuming – Emissions Free

Christopher J. Bourg, Director of Special Services South, Aquilex HydroChem, will review the different types of technology available to control emissions on vacuum trucks and the advantages and disadvantages of each type of system. Find out how different emissions control systems can affect your work schedule, and discover ways to reduce time and resource constraints.

Wednesday, September 11, 2013

Understanding the Power of Vacuum and How Industrial Vacuum Loaders Work

"Professor" Phil Stein, a consultant in the industrial vacuum industry, will present this "nuts and bolts science lab" for first-time users and experienced vacuum truck operators. Topics include basic types of trucks, how pressure works, measuring vacuum and pressure, why hose diameter and length is important, viscous materials, air mover configuration, special operations, when things go wrong, and major safety concerns.

Maximizing Efficiency in Manual Waterblast Applications

Gary W. Toothe, CET, Training Manager, FS Solutions, will discuss how to best determine proper nozzle configurations for pipe cleaning, tube cleaning, and surface cleaning. Mr. Toothe will share tips to determine thrust in pipe cleaning and back thrust in surface cleaning, and he will offer suggestions for maximizing production.

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Emerging Technology, New Applications - Paper Presentations

- Abrasive Water Jet Cutting (AWJC) of Co-Cr-Mo Alloy Investment Castings in the Medical Device Industry, by *M. Cashman, L. Soo, D. Shepherd, A. Rabani and S. Ramirez*
- Abrasive Waterjet Texturing as a Method to Enhance the Embedment of Metallic Inserts in Composite Materials, by *A. Alberdi, T. Artaza, J. Olite, J.L. Latapia and A. Suárez*
- An Experimental Study of Thermally Enhanced Abrasive Water Jet Machining of Hard-to-Machine and Ductile Materials, by *D. Patel and P. Tandon*
- Application of Abrasive-Waterjet for 3D Machining, H.-T. Liu
- Characteristics of Air Coated Abrasive Suspension Jets Under Submerged Condition, by *H. Ito, G. Peng and S. Shimizu*
- Experimental Study of a High Efficient Jet Nozzle in Coiled Tubing Radial Drilling Technique, by *D. Ma, G. Li, Z. Huang, J. Niu, X. Song, and R. Guo*
- Extending Ability of the Micro-hole Radial Horizontal Well Drilled by Hydrojet, by *H. Chi, G. Li, Z. Huang, S. Tian and F. Di*
- Hydrael Energized Fracturing Mixed Nitrogen Treatment Design and Parameters Calculation, by *C. Cai, G. Li, and Z. Shen*
- Impact Force of High Pressure Waterjets, by *D. Wright*
- Interpretation of Intricate Drawings into Actual Objects, by *V. Cutler*
- Is Lowering of AWJ Cutting Costs by an Increasing Pressure is Economic Feasible?, by *A. Perec*
- Mechanism of Hydraulic Pulsed and Cavitating Jet Improving ROP and Application in China Offshore Drilling, by *H. Shi, G. Li, and Z. Huang*
- Paint Removal of Airplane & Water Jet Application, by *S. Xue, J. Su, Z. Chen, F. Lu, and H. Zhu*
- Present Situation and Development of Chinese Cleaning Industry, by *C. Ma*
- Pressure Boosting Effect in Perforation Cavity During Supercritical Carbon Dioxide Jet Fracturing, by *Y. Cheng, G. Li, H. Wang and Z. Shen*
- Pulsed Jet to Improve Drilling Speed in Deep Wells, by *L. Cui, H. Wang, and F. Zhang*
- Pumping Efficiency's Effect on Cutting Optimization, by *A. Henning and P. Miles*
- Rz: A Better Measurement of Abrasive Waterjet Cut Surface Finishes, by *A. Henning and P. Miles*
- Reconditioning of Solid Radioactive Waste Using Forced Pulsed Waterjet (FPWJ), by *A. Tieu, B. Daniels, M. Xu, W. Yan and M. Vijay*
- Refractory Removal by High Pressure Waterjet, by *D. Wright*
- Removal of a Failed Coating System from a High-rise Using Automated UHP Water Jets, by *T. Kupscznk and J. Van Dam*
- Robot-assisted Displacement Osteotomy by the Abrasive Waterjet – Concept and Technical Realization, by *D. Zaremba, R. Westphal, C. Krettek, F.M. Wahl, Fr.-W. Bach, and T. Hassel*
- Study on Photoelectric Confrontation of Water Mist Screen System, by *B. Ren, H.J. Zhang, HG Xu and M. Guan*
- Technical and Economical Comparison of Waterjet and Abrasive Blast Methods to be Used in De-Coating and Cleaning Processes, by *H. Teimourian*
- The Use of High Pressure Water Jets to Improve Performance of Rotary Cutter Head Dredges from the Inside Out, by *C. Wyatt and H. Miller*
- Top Ten Challenges in Milling Using Abrasive Water Jet Machining Process, by *VKG Thammana*
- UHP/LV Waterjet – Surface Re-Texturizing for Bitumen Flushing/Bleeding, by *S. Robinson*
- Verification of Turbulent Correlation and Impact Study of High-Pressure Abrasive Water Jet, by *C. Kang, H.X. Liu and M.G. Yang*
- Wet Abrasive Blast – When Will We Ever Get a Standard?, by *L. Frenzel*

Hotel Information - Hilton Americas - Houston

The Hilton Americas - Houston, 1600 Lamar, Houston, TX 77010, is directly connected to the George R. Brown Convention Center via two indoor sky-bridges. The room rate is \$165 single/double occupancy. For reservations, call toll-free (800)236-2905, contact the Hilton directly at (713)739-8000, or register online (a link can be found on the WJTA-IMCA website). When calling be sure to ask for the group rate for WaterJet Technology Association (WJTA)-Industrial & Municipal Cleaning Association (IMCA).

Monday, August 17, 2013, is the deadline for guaranteed room availability. Reservations received after August 17 will be confirmed on a space available basis. Rooms may still be available after August 17, but not necessarily at the rate listed above.

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 - Exhibit Hall - Wednesday, September 11**. Includes admittance to the exhibit hall, boot camp, and live demonstrations on Wednesday (9/11). (Valued at \$30.)
- Expo Pass — Two-Day****COMP**
- Exhibit Hall - **Tuesday & Wednesday, September 10 & 11**. Includes admittance to the exhibit hall, boot camp, and live demonstrations on Tuesday, (9/10) and Wednesday, (9/11); and the Industry Appreciation Reception on Tuesday (9/10). (Valued at \$100.)
- Full Conference**\$ 299.....\$ 359.....\$ 359.....\$ 419.....= \$ _____
 Registration includes admittance to the Industry Appreciation Reception on Tuesday (9/10), and exhibit hall, boot camp, emerging technology, new applications sessions, and live demonstrations on Tuesday (9/10) and Wednesday (9/11). You will also receive one copy of the *Conference Proceedings* on CD-ROM and two (2) lunch vouchers that can be used on Tuesday and Wednesday (one per day).
- Author Registration**\$ 229.....\$ 229.....\$ 229.....\$ 229.....= \$ _____
 Registration includes all the activities in the Full Conference. Author Registration applies to individuals presenting a paper during the emerging technology, new applications sessions or listed as an author on a paper.
- Combo**\$ 399.....\$ 459.....\$ 459.....\$ 519.....= \$ _____
 Registration includes all the activities in the Full Conference PLUS the Pre-Conference Seminar on Monday (9/9). You will also receive one copy of the *Conference Proceedings* on CD-ROM, one (1) lunch ticket, and two (2) lunch vouchers that can be used on Tuesday and Wednesday (one per day).
- Pre-Conference Workshop - Monday, September 9**\$ 119.....\$ 179.....\$ 179.....\$ 239.....= \$ _____
 Registration includes admittance to the Pre-Conference Workshop and lunch.
- Student**\$ 20.....\$ 20.....N/A.....N/A.....= \$ _____
 Registration includes admittance to the Pre-Conference Seminar on Monday (9/9); and Industry Appreciation Reception on Tuesday (9/10); exhibit hall, boot camp, emerging technology, new applications sessions and live demonstrations on Tuesday (9/10) and Wednesday (9/11). Registration does **NOT** include a copy of the *Proceedings* or lunch ticket/vouchers. **NO** discount is available for students that are not members of WJTA-IMCA. WJTA-IMCA student members must be enrolled **full-time** in a university graduate or undergraduate program.
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Cancellation Policy: Fees will be refunded in full for cancellations received at least four (4) weeks prior to the Conference. Cancellations received more than ten (10) days and less than four (4) weeks prior to the Conference will be subject to a \$50 charge. No refund will be made for cancellations received less than 10 days prior to the Conference. However, substitutions may be made at anytime. Refunds will not be processed until after the Conference.

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Barton International Launches a New Website and E-store

Barton International has launched a new website and e-store. The recently redesigned site offers a fresh look with easy-to-navigate pages focused on the needs of customers. Navigation is optimized by using graphic links to each of Barton's primary product lines: garnet abrasives and waterjet parts.

The site includes extensive product information to help customers understand Barton's complete range of abrasive solutions. Users can find technical data and literature in the document library and view product images in the waterjet parts e-store. Created with the user experience in mind, the site is compatible with most browsers and mobile devices.

"The launch of the new website, which offers quick and easy access to information, is part of Barton's ongoing efforts to enhance the quality and availability of information to customers and industry professionals," says Randy Rapple, president of Barton International.

The e-store offers a complete selection of replacement parts for abrasive waterjet cutting equipment including genuine OEM parts and Barton exclusive products. Free shipping is available for online parts orders of \$300+ of most items within the continental United States. Visit store.barton.com for details.

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Current and Potential Robotic Abrasive Waterjet Systems, from page 14

During this procedure the operator will program the path, consisting of lines and circles and also define speeds, corner positioning, etc. and assign any I-O (inputs and outputs) to control or monitor external functions. These external devices can be the nozzle, vacuum system, clamps, etc. The robot can also be oriented in a variety of positions to suit the work environment.

Moving forward from this manual procedure to an offline programming environment will enable elimination of the teach pendant. This will require a custom post processor and process-specific offline programming software relative to the particular brand of robot. In order to do this, the robot, the end effector TCP and the work holding fixture must be defined in the real world. As with the gantry systems, robot rigidity is also a very important factor to ensure high accuracy calibration.

Robots are integrated in several system styles such as open and enclosed systems, Figure 5. Also, more than one robot can be used on the same part. In this case, offline programming will be critical.

2.3 AWJ Robotic Cutting

Waterjet robotic cutting has been introduced early due to the advantages of both robots and waterjets. For example, waterjets (without abrasives) have been used for cutting and trimming a wide range of automotive interior materials (5-7). Among these are:

- Floor carpets and roof liners
- Dash sound insulation material



Figure 5: Typical Robotic Cutting Cells: Open and Closed

- Plastic/fabric composites (i.e. rear shelf and transmission tunnel components)
- Sheet molded composites (SMC)
- Glass fiber components (body panels etc.)
- Carbon fiber and/or aramid fiber composite

Recently, abrasive waterjets (AWJ) were integrated with robots to capitalize on their flexibility. However, this introduced new significant challenges related to abrasive feed, accuracy, speed range and safety. Figure 6 shows an example of an AWJ-equipped robot arm.



6-axis robot on stationary frame



6-axis robot on a linear slide

As discussed above, robots can be mounted in different ways based on the application. For AWJ use, floor mount AWJ systems have been

commercialized. Also, Figure 7 shows alternative methods to using robotic AWJ arms either on a stationary frame or on a single axis gantry.

3. SELECTED AWJ ROBOTIC APPLICATIONS

3.1 3D AWJ Cutting and Shaping

It has been shown that AWJ has great potential for 3D cutting and shaping (8, 9). Due to the 6 degrees of freedom offered by robotic arms, 3D machining and shaping with AWJ may become highly feasible. For example, a complex geometry as shown in Figure 8 (left, center) can be machined without re-orienting the workpiece. A block of material can be cut to produce a near net shape part as shown in Figure 8 (right). The addition of a rotary axis will allow machining of additional features such as the surface of revolution. This can be a significant time saver in an actual production environment.



Figure 6: Abrasive Waterjet (AWJ) Cutting Head

(continued on page 25)

Current and Potential Robotic Abrasive Waterjet Systems, from page 24

For example, machining the nozzle injector shown in Figure 8 (right) can be started by cutting segments out of the original raw bar or rod and then some sections can be turned to minimize the subsequent milling and finishing processes. Analysis showed that over 50% time saving can be obtained for the injector nozzle part but equally important, not all the material needs to be converted to chips and thus a higher residual value is obtained with this approach. Cutting on 3D parts can also be accomplished as shown in Figure 9.

3.2 Tire Cutting

In the mining industry, giant tires are used on several pieces of mining equipment. These tires may be over 2 m in diameter and weigh over a metric ton. They are subject to the manufacturer's scrutiny to avoid costly premature failure. An AWJ tool has the significant advantage of being non-thermal and non-mechanical, making it a most suitable tool for cutting tires to enable true structural analysis for quality assurance testing of the rubber and steel wire composition in the tread, sidewalls or bead. Typically "dog-bone" sectioning of the tire is made at several locations for testing and evaluation. Also, when tires fail the failed areas are cut out. A 6-axis robot equipped with an AWJ is manually programmed by the operator to dissect and remove any failed relatively-small section or complete cross section of the tire. Figure 10 shows



Figure 10: Tire Cutting with Robotic AWJ

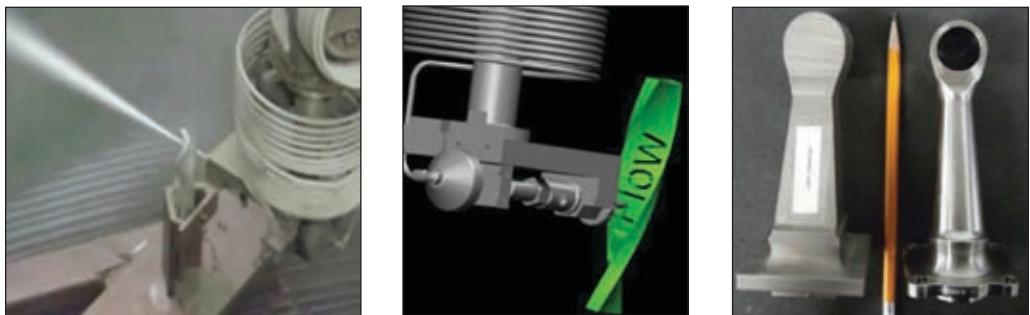


Figure 8: Complex and Near Net Shape Cutting



Figure 9: Cutting on 3D Parts

a robotic AWJ used to cut up coupons from a large tire. The full side wall was cut by mounting the tire on a turntable and rotating it.

3.3 Stone Cutting

Combining state-of-the-art technologies to production-grade work cells is the next evolutionary step for multi-axis robots. Utilizing a vision system and photographic imaging for identifying part location and alignment to tool path math data with user friendly software allows simple operator interface control of the machine tool to cut complex shapes in materials such as stone with AWJ technology and straight linear cuts using mechanical diamond circular saw technology for optimal speed. Figure 11 shows a robotic end effector with both an AWJ cutting head and a saw. A common cell is to use two work stations (cutting tables) as shown in Figure 11. This dual table design maintains an efficient use of plant floor space by locating the robot centrally between the two cutting tables, allowing one side to be cutting whilst the opposite side is clear and open for operator loading and unloading, thus maintaining continuous productivity.



Figure 11: Dual Table Robotic Stone Cutting System

(continued on page 26)

Current and Potential Robotic Abrasive Waterjet Systems, from page 25

3.4 Degating and Deflashing

Complex castings may require gates and risers in unusual places to achieve the desired shape or product (see Figure 12). In some cases the cut line is not linear and is problematic for conventional mechanical bandsaws, circular saws or dedicated tooling of shear brakes to handle. In these cases, operator safety is also a consideration due to broken blades or bodily injuries. The AWJ tool offers great advantages for this application because of its omnidirectional cutting capability and absence of any heat affected zones. However, precaution must be used regarding the direction of the emerging jet on the “back side” of the cut. The programming is done manually

by teaching the path of the cut. In some sophisticated systems, machine vision can be used instead. In the cases where the exiting jet may affect the casting, protection plates may be used or the area is avoided and then cut mechanically. Special cutting heads have been used to reach into tight spaces or to cut adjacent to a wall. Mounting the casting on a turntable and subjecting it to the AWJ will result in the cleaning and removal of some flash material. The abrasives may be turned off in some cases to avoid cutting or eroding the workpiece.

3.5 Composite Trimming

Most trimming requirements are within the accuracy of robotic arms. This makes them of high potential for composite trimming using waterjets which is needed in many applications. For example, carbon fiber composites are used in aircraft structures and they are difficult to machine with conventional tools (10, 11).

(continued on page 27)



Figure 12: Examples of Cast Parts for Waterjet Degating and Deflashing

TST Sweden Waterjet Protection

TST Sweden AB continuously develops and improves its products. Suggestions from distributors and end users help in the effort to make better protective clothing. Following are improvements on TST Sweden's trousers, overalls, aprons, and gloves.

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Current and Potential Robotic Abrasive Waterjet Systems, from page 26

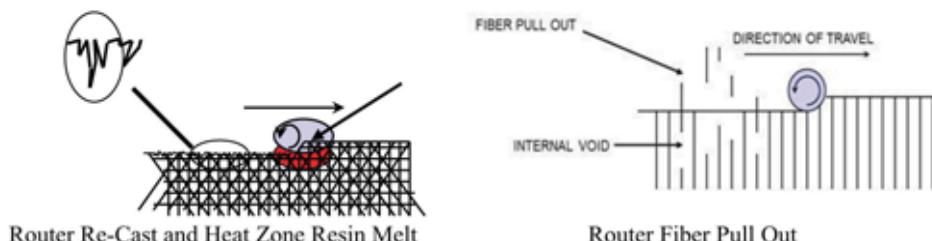


Figure 13: Anomalies of Cutting Campsites with Mechanical Tools

These tools often result in a localized heat affected zone which melts the resin, inducing a recast state and evidential micro cracks as illustrated in Figure 13. Also, they may cause internal voids due to fiber pull out, Figure 13. In addition, controlling the composite cut surface finish is difficult because of the anisotropy of the material, unlike with AWJ cutting which is much less sensitive to this ef-

fect. AWJ offers great advantages over conventional tools regarding speed, lifetime, and quality. For example a 0.400 inch (10 mm) router bit will last on average 40 minutes to 1 hour, whereas the average AWJ nozzle with a 0.040 inch (1 mm) stream diameter will last over 80 hours of continuous cutting. A great advantage of AWJ is that it is non-thermal (no heat or mechanical stresses), causes no fiber

pull-out, causes no delamination and the cutting speed is typically twice as fast. The fixturing required can be designed very lightweight as the process induces less than 4.4 lb (2 kg) of thrust force while cutting. Figure 14 shows a micrograph comparing AWJ to mechanical cutting.

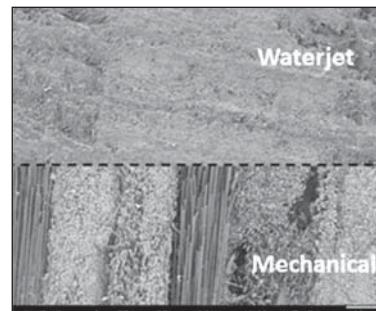


Figure 14: Scanning Electron Comparison Data Image (12)

(continued on page 28)

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3.6 Aircraft Applications

AWJs have been used extensively in many aircraft composite cutting and trimming applications since the late 1980s. Example aircraft and corresponding AWJ-machined components are given in reference (4).

Five-axis gantry systems with dual masts for waterjet and mechanical routing have been the standard

systems for the above applications. Six-axis robots promise to complement the standard gantry systems for some trimming applications. Figure 15 shows a model of a robotic AWJ trimming unit. Observe that the catcher cup arm needs to swing (6th axis) as not to collide with the structure being trimmed. Instead of manipulating the jet, the workpiece may be manipulated with a robotic arm under a fixed jet. This approach may be useful for some applications.

In addition to shape trimming, robots may also be useful for end trimming and shape cutting. For example, 5-axis AWJ was used to drill access holes at the roots of stringers which can also be done with 6-axis arms using an appropriate end effector.

3.7 Jet Engine Hole Drilling Application

The use of robotic arms in jet engine applications has been limited to stripping applications using plain waterjets. Typically, cutting and drilling in jet engine parts requires more accuracy than robots may be capable of providing and thus many roughing applications could benefit from AWJ robotic cutting. For more accurate cutting of a given part, compensation could be used.

A significant advantage of using robotic arms is the ability to use more than one jet on the same part. For example, a number of robots could be used to drill small diameter holes on a nacelle part. It was shown that 30,000 holes were drilled at about 0.9

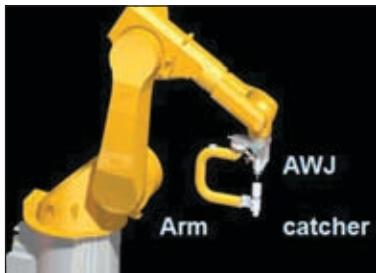


Figure 15: Trimming by either Manipulating the Part or the Jet

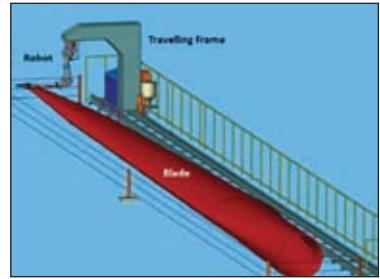
sec hole-to-hole time, so one jet will drill a part with 100,000 holes in about 30 hrs, and thus four robots will drill this part in one shift. Figure 16 (left) shows a composite nacelle mock-up drilled with AWJ, while Figure 16 (right) shows another example of drilling through silicon carbide/silicon carbide composite flame holder part inside a jet engine. These holes are drilled at several angles to achieve maximum cooling effect. With a 6-axis robot, and after tool center point (TCP) compensation, parts can be drilled to better than 0.25 mm location accuracy which is closer to robot repeatability specification.



Figure 16: AWJ Hole Piercing

3.8 Wind Turbine Blade Trimming

Wind turbine blades are made of fiberglass, and they have a round root and an aero foil shape blade. To trim the seam between the halves of this blade, the current approach is manual, using mechanical tools. An alternative approach is to use 6-axis robots. Figure 17 shows a robot-mounted frame rail for the trimming of relatively long wind turbine blades. The seam between the upper and lower shell is trimmed using a special nozzle that cuts very close to the root of the joint.



Robotic Wind Turbine Blade Trimming



Wind Turbine Blade

Figure 17: 6 Axis Articulate Robots on a Linear Rail for Wind Turbine Blade Trimming

(continued on page 31)

Jet Edge, Sponsor for “Gateway to Europe” International Trade Conference

Jet Edge Inc. will be one of the corporate sponsors of the upcoming “Gateway to Europe International Trade Conference,” June 4-5 at the Radisson Plaza Hotel in Minneapolis. The conference is hosted by the Minnesota District Export Council (MN DEC) in cooperation with the U.S. Commercial Service.

With over 300 companies expected to participate, this international trade conference offers U.S. businesses unique opportunities to develop networks, devise strategies, and expand knowledge of current economic and political trends across the region. Conference attendees will have the opportunity to pre-schedule one-on-one meetings with more than 25 senior commercial diplomats from markets in Western, Central, and Eastern Europe, Russia, Turkey, Ukraine, and Kazakhstan. They also will have the opportunity to identify the best business opportunities in multiple markets and attend keynote addresses by leaders from private industry and government. Markets covered during the conference include Austria, Baltics, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Kazakhstan, Netherlands, Norway, Poland, Portugal, Romania, Russia, Serbia, Slovak Republic, Spain, Sweden, Turkey, Ukraine, United Kingdom, U.S. Mission to the EU, and U.S. Mission to IAEA.

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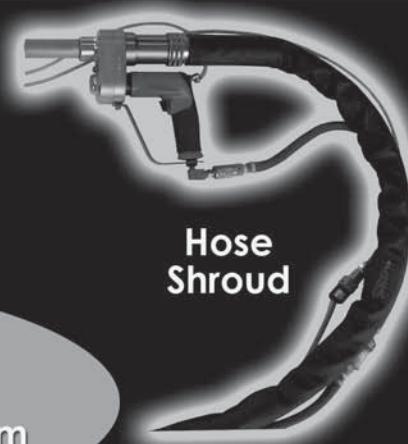
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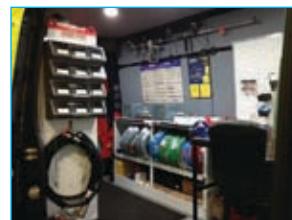
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Jetstream Introduces Mobile Parts and Service Van for Customers in Midwest

Jetstream of Houston, LLP, introduced a mobile parts and service van in the Midwest region of the United States to assist industrial cleaning contractors during major shutdown work. As the first on-site StoneAge® tool repair center, the Jetstream van is also equipped to provide timely repair solutions for StoneAge waterblasting tools.

"Our new mobile parts and service van provides fast, affordable solutions to help our professional cleaning customers in the Midwest better manage their waterblasting jobs and keep downtime to a minimum," said Mike Taylor, Midwest regional district sales manager at Jetstream. "With the van, parts and service solutions from Jetstream are literally just around the corner from many of our customers."

The mobile parts and service van, which is custom wrapped with the



Jetstream brand identity, currently serves customers in Illinois, Indiana, Michigan, Ohio and West Virginia. Customers can purchase a wide range of Jetstream parts, accessories and personal protective equipment directly from the van.

To assist cleaning contractors in ensuring available parts and accessories for shutdowns, the Jetstream mobile parts and service van can be scheduled in advance. Parts and accessories can be delivered to a customer during the van's normal route call with advance notice.

As a distributor of StoneAge tools in North America, Jetstream's mobile parts and service van features the machine expertise and tooling capabilities to repair select StoneAge waterblasting tools on the job site, saving time and money.

"The technicians travelling with the Jetstream mobile parts and service van have the training and expertise to repair StoneAge products on site, rather than requiring customers to rely on the StoneAge service location in Durango, Colorado," Taylor said. "This eliminates shipping costs and ensures that repaired tools are back in the operator's hands with the least amount of downtime as possible."

For more information, visit www.waterblast.com or call 1-800-231-8192.

OMAX® Corporation Honored for Leadership in Educational Outreach, from page 16

OMAX has participated in rotating internship and co-op programs offered by some of the top technical colleges and universities in the United States. Educational institutions, such as Kettering University, Renton College, the University of Washington and Washington State University, work closely with OMAX to offer students real-world experience and hands-on training in the manufacturing industry.

"We are truly honored to have received the *Inspire* Award for our educational outreach. Through our educational programs, we are exposing students to engineering and manufacturing practices that will help them when pursuing a career in manufacturing. We also make it a



OMAX Corporation continues support of Aviation High School's First® Robotics team, Skunkworks Robotics. The partnership marks the company's sixth year of mentoring talented students interested in obtaining engineering and manufacturing skills.

point to generate job opportunities for graduating students," concluded Cheung.

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4. CONCLUSION

5-axis robots have been in use with AWJ cutting of composites since the late 1980s for a wide range of aircraft components, achieving accuracies of +/- 0.002 inch (0.05 mm). The use of specific, rigid 6-axis robots is now emerging as their accuracies are proving to be better than +/- 0.010 inch (0.25 mm). The calibration process allows the robot and the workcell to become more "accurate," by precisely defining the actual or "true" kinematic model of the robot-cell and offsetting and compensating for the differences to the CAD or "ideal" kinematic model. The use of robotic cutting and drilling cells is emerging for such parts as composite nacelles and small scale parts such as clips, fairings, covers, etc. as a very cost effective solution.

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Patrick O'Leary Joins Stutes Enterprises

Patrick O'Leary has joined Stutes Enterprises. Mr. O'Leary is an industry veteran with over 15 years of experience servicing the industrial vacuum and hydro-blasting markets. His first exposure to the business came in the mid 90's when his father, Mike O'Leary, took over as sales manager, and later as minority partner, in Louisiana's Vactor dealer at the time, Shamrock Pipe Tools. Shortly thereafter Mr. O'Leary went to work developing Vactor, Guzzler, and Jetstream's burgeoning used equipment business, which would later become FS Solutions.

After leaving the Federal Signal Group, Mr. O'Leary took a regional sales position at GapVax, bringing over \$6 million in sales during his first year. Since then, Mr. O'Leary has helped develop sales and rental markets for manufacturers, rental, and industrial service companies through his own venture Vactruckman, LLC. Mr. O'Leary will be based out of Stutes Enterprises' Gonzalez, Louisiana, office, and he will be heading up the sales and business development efforts in Louisiana and the Gulf States Region.



Patrick O'Leary

Jetting Away the Impurities, from page 10

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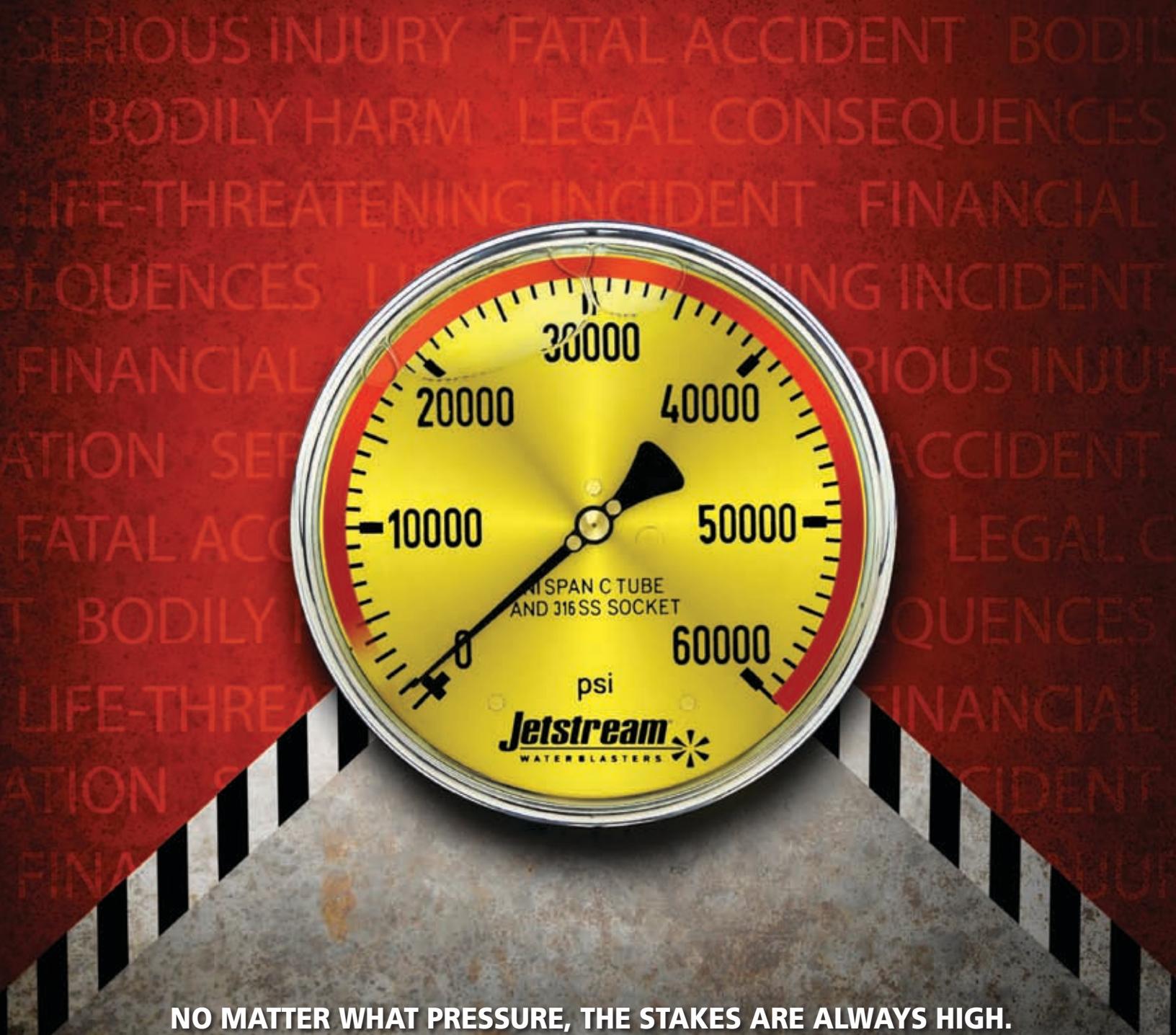
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