Waterjet Technology and Applications – Deepwater Subsea

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Abstract

Waterjet technology is now available for application in deepwater (3,000m+) environments. This technology offers several important advantages over existing technologies and opens up new opportunities for continued advancement and refinement of deepwater maintenance, repair, salvage, and emergency response techniques.

Advances in waterjet intensifier pump technology over the past year prove that waterjet technology need not be limited to surface operations, but in fact may be applied in deepwater subsea environments in a highly beneficial way. There have been several demonstrations of the implementation of waterjet cutting systems on subsea structures from the surface, but the effectiveness of these techniques is limited to about 365 meter depth.

Waterjet technology may be applied as a cutting tool (abrasivejet) in emergency response situations or as an ultra-high pressure stream of water used for coating or marine growth removal in applications such as isolation of welds for inspection. It also may be used as a tool to provide turbulence in a stream of methanol for tasks such as hydrate remediation. As a cutting tool, an intensifier-style pump is used to pressurize a stream of water (seawater is acceptable) to ultra-high pressures (3,900 bar). With the addition of abrasive, it is effective at cutting steel up to 250 mm thick. The tool in a waterjet system cannot bind in the cut to jeopardize asset integrity, and it eliminates the hazard of igniting trapped pockets of gas during cutting.

Waterjet technology has been extended into the deepwater subsea space during the past year. Inclusion of an intensifier-style subsea waterjet system in the collection of emergency response assets will give another option for cutting, salvage, and conduct of rapid de-mobilization operations. Application of this technology in deepwater environments is in the early stages, but the underlying technology has been proven to be effective.

Introduction

Successful operational demonstration of an ultra-high pressure waterjet intensifier at depths in excess of 3,000 meters during 2010 opens up many new opportunities for application of subsea waterjet cutting.[1] This extension of waterjet technology allows for cutting of steel and other materials, as well as for hydrate remediation and isolation of valves, ports, caps, bolts and weld seams.

Waterjet cutting is sometimes known as abrasive jet cutting when referring to its ability to cut through steel. This is done because the process relies on entrainment of a sufficient amount of abrasive to allow for the erosive cutting process to occur. In this paper we refer to the process generically as waterjet because both processes rely on the same intensifier and pump technology to create the ultra-high pressure stream of water.

Waterjet cutting is a cold cutting process. It relies on millions of abrasive particles entrained in the water stream to collide with and erode the target material. Unlike thermal cutting processes such as welding, flame, and even grinders, saws, and diamond wires in some situations, the waterjet cutting process is a cold cutting process and does not generate enough thermal energy to ignite most confined gases.[2] In addition to the benefit of increased safety to both personnel and equipment, the waterjet cutting process does not introduce a heat affected zone (HAZ) into the material being cut. This leaves the original metallurgical properties of the material intact, reducing the possibility of introducing stress fractures and other physical deformities to the work piece. Secondary operations such as milling and other machine work do not have to contend with hardened material after the waterjet cutting process is complete.[3]

Discussion of Current Technology and Methods
There are a variety of methods employed by both divers and ROV crews today for routine maintenance and repair tasks in the subsea environment. Underwater welding and flame cutting techniques are well known and both techniques are used to accomplish welding and cutting missions. These techniques are fairly well understood and thus yield predictable results for many missions.[4] However, significant safety risks have placed increased pressure on dive operators to reduce reliance on these techniques.[5]

Saws and diamond wires are hard cutting tools designed to sever a pipeline or structural member. These tools may have advantages over waterjet cutting in terms of efficiency of the cut and are applicable to inert structures and situations where the tooling is relatively easy to apply. Both of these tools must enter into the kerf of the cut in order to complete it. This requirement leaves the tools vulnerable to mechanical binding in the cut, possibly exposing the diver or ROV asset to the risk of falling structural members while attempting to free it from the cut. In an emergency situation where a pipeline must be cut under full flow conditions, as was the case in the Deepwater Horizon oil spill situation, a hard tool such as a saw or diamond wire suffers significant risk of binding in the cut because of the large forces imposed on the tool, in the cut, by the high velocity flow inside the pipe being cut.[6] Whereas both of these tools may be fairly easy to apply on small members, they may become significantly more complicated to apply remotely, and on large members, because of their large size and the complexity of the tool path.

Shears may be effectively employed in salvage operations where structural integrity of the salvaged piece is not of concern. In the situation of repairs and maintenance, shears are generally not used, in the interest of preservation of the geometrical and structural integrity of the subject work piece.

Waterjet technology may be applied as a cutting tool (abrasivejet) or as an ultra-high pressure stream of water that is useful for coating removal, pre-inspection weld isolation, and marine growth and rust scale removal. It also may be used as a tool to pump methanol or other media at ultra-high pressure for tasks such as hydrate remediation. In a cutting system, an intensifier-style pump is used to pressurize a stream of water (seawater is acceptable) to ultra-high pressures (3,900 bar). Abrasive garnet is added to the resulting stream of water and an efficient cold-cutting tool is produced. This tool, the abrasive-entrained-in-jet stream of water, is effective at cutting almost any material, and at thicknesses as much as 250 mm in steel. This cutting method eliminates the hazard of igniting trapped pockets of gas. As a coating removal or hydrate remediation system, seawater or methanol is pressurized by the intensifier pump to 3,900 bar and several streams are formed, and rotated, to produce a uniform application of energy on the subject work piece. The resulting waterjet stream(s) have sufficient energy to remove even the most difficult coatings (epoxy, concrete, marine growth, rust scale) with a greatly minimized risk of cutting into, or through, the substrate of the subject work piece.

Current Limitations of Waterjet Technology
Until recently, waterjet equipment was not suitable for application in subsea environments because it was not able to withstand the ambient environment experienced by subsea equipment. Several considerations of the subsea environment, including high ambient pressures, cold water temperature, and the corrosivity of seawater must all be made and factored into equipment design, to successfully deploy waterjet pumps subsea.

To date, there have been several demonstrations of the application of waterjet cutting on subsea structures, from the surface, but limited by pressure losses to about 365 meter depth.[7] These applications have largely been limited to cutting of round pipes and caissons from either the interior or the exterior of the structure. These applications of the waterjet process represent the normative technology with respect to subsea waterjet capabilities and are limited to approximately 365 meter depths. This limitation is due to the pressure losses realized inside the ultra-high pressure tubing, and the ability to properly deliver the abrasive uniformly to the cutting head at these depths.

Subsea Waterjet Technology
In July 2010, Chukar Waterjet demonstrated an intensifier style waterjet pump capable of subsea operation. The intensifier was operated in the water column between the surface and 1,430 meter depth. Water temperatures were as cold as 3 degrees Celsius (37 ^{o}F). Seals and components on this unit were modified to withstand the environmental pressure of 150 bar (2,100 psi), and to withstand extended and repeated exposure to salt water and to methanol. With this advancement of waterjet intensifier pump technology, the depth restriction is removed and waterjet technology becomes available to all subsea projects.

Since abrasive is used to produce a reliable cutting tool in a waterjet system, efficient and continual abrasive delivery to the waterjet cutting head is a critical factor to be considered in the deployment of a subsea waterjet cutting system. To become truly depth independent, this capability must be built into the waterjet skid that is to be deployed subsea. Technology recently developed at Chukar Waterjet will allow enough abrasive to be carried on the subsea waterjet skid to provide cutting of 50+ m (160 ft.) of 12 mm (1/2 in.) thick steel, independent of depth.

The use of waterjet technology to displace conventional tooling in subsea applications provides several potential safety, environmental, and performance benefits. As discussed in the introduction, waterjet cutting is a cold cutting process and does not generate enough thermal energy to ignite most confined gases. In addition to the benefit of increased safety to both personnel and equipment, the waterjet cutting process does not introduce a heat affected zone (HAZ) into the material being cut. This leaves the original metallurgical properties of the material intact, reducing the possibility of introducing stress fractures and other physical deformities to the work piece. Secondary operations such as milling and other machining work do not have to contend with hardened material after the waterjet cutting process is complete as do secondary operations following flame cutting and welding operations.

Waterjet tools also are referred to as soft tools. In addition to their freedom from binding in the kerf of the cut, this characteristic allows them to be employed as pattern cutting tools, capable of producing non-linear cutting profiles. One example of a non-linear cut profile is a non-circular pattern in the surface of a pipe where a new intersecting pipe will be inserted.

The ability to run reliably for an entire shift is highly desirable in offshore operations. This ability minimizes losses in productivity caused by launch and recovery operations. Waterjet systems based on *intensifier* technology are very reliable and require infrequent maintenance. Intensifier-style pumps are especially well suited to operation in deepwater because, unlike positive displacement pumps, a properly designed intensifier system is able to dynamically compensate for changes in the depth-dependent ambient pressure of the work environment. Intensifier-style systems also are able to easily accommodate flow rate and desired pressure variations in the output stream, enabling the user to trim or enhance the tool output in situ.

Subsea waterjet technology is applicable to deepwater environments, as a tooling system to be used by an ROV as discussed in the bulk of this paper, or as a tooling system to be used by a dive team in shallow waters, to saturation dive depths. Deployment of a waterjet intensifier skid can be visualized as a process that utilizes the same methods that are currently used to deploy ROV assets. A single umbilical, carrying electrical power and communications, provides the lift needed to lower/raise the skid into the sea. Critical in the consideration of personnel safety and integrity of assets, the single umbilical minimizes the cable count and by extension, reduces risk of entanglement with a propeller or other equipment operating nearby.

Tooling, *within* the waterjet system context, simply refers to the method or machine chosen to apply the waterjet stream to the work piece. The "tooling" may be applied by hand or robotic arm, with the user directing the waterjet stream without assistance of controlled motion. In practice, it is fairly easy to apply hand-held tooling to cleaning processes, but quite difficult to cut steel greater than 6 mm thick. Tooling for cutting a pipe from the interior or exterior is available from many vendors. In some cases, adaptations need to be made to allow the tooling to carry the waterjet cutting head. Linear cutters and hole cutters also are available and many require the same type of modifications. It is expected that modifications of these tools to carry waterjet cutting heads will follow rapidly as waterjet technology gains acceptance in subsea applications. Further, the tooling, whether it is designed for ROV compatibility or for diver compatibility, will rely on the same waterjet skid to produce the waterjet stream. This system flexibility will allow the waterjet system to be deployed in the water column, independent of depth.

Applications of Subsea Waterjet Systems
Although application of subsea waterjet systems is in its infancy today, it is useful to visualize the many possible applications that could benefit in the future.

Emergency Response: The application that largely drove recognition of the need to produce this paper was that of emergency response. Extension of waterjet technology into the subsea environment provides another tool that could potentially be used to aid in the desired very-fast response to a disaster such as occurred in 2010 in the Gulf of Mexico on BP's wellhead in the Macondo reservoir. Availability and deployment of a deepwater subsea capable waterjet system could, because of its unique *cold-soft tool* characteristic, be applied in such a situation to rapidly produce a clean cut on the wellhead to make it ready to accept a cap or diversion device. Further, the same system could then be used to prevent build-up of hydrates prior to and during the capping process – enabling the response team to focus on the primary task.

Hydrate Removal: Effective removal of hydrates, or "hydrate ice," can be accomplished by melting them with methanol. In the case of contingency planning, more efficient means of hydrate removal allow faster disconnect times in the event assets have to be removed from a work zone. Pressurized methanol from an intensifier pump can be even more effective because the pressurized stream is able to break the hydrates into small fragments, thus exposing more surface area to the chemical melting process of the methanol.

Cutting: Waterjet cutting can be used to effectively cut caissons, pipes, plates, beams, valves, bolts, and other structures during repair, maintenance, and salvage operations. Waterjet cutting requires the addition of an environmentally inert abrasive (garnet) to the cutting stream. The ideal subsea waterjet cutting skid would carry enough abrasive to be able to perform typical cutting operations (50% cutting throughput) and remain useful for an entire shift. This translates into nearly 50 m (160 ft.) of linear cutting on 12 mm (1/2 in.) thick steel during a shift. Waterjet cutting is effective on most known materials today including: steel, aluminum, concrete, epoxies, ceramics, alloys, fibrous mats, and many others.

Salvage: Waterjet cutting is a cold-cutting process that is proven to be a safe alternative to hot-cutting methods such as torches, hot sticks, or even grinders and saws. This is because the risk of igniting trapped gas pockets is greatly reduced. Because a waterjet stream also is a soft tool, waterjet cutters are free from the risk of becoming bound in the kerf of the cut. Waterjet is also easily operated remotely on mechanized frames, enabling divers to stay back from the structure and away from the stored energy in overhanging beams and structures. This trait, along with the minimization of lines and cables overboard, provide a system that reduces risk to the safety and integrity of both personnel and hard assets.

Cleaning: Pressurized at up to 3,900 bars, a waterjet system can be used to provide ultra-high pressure to a tool in a rotating multi-stream configuration to provide an effective method of isolating welds in preparation for inspection. Application of waterjet in this way does not change the profile or alter the metallurgical properties of the substrate. Thus it may be considered a non-destructive method.

Coating removal: Removal of paints, epoxies, concrete, rust scale, and marine growth also are typical uses of waterjet systems. This process is very similar to the above-mentioned cleaning process and often is used to prepare a surface for acceptance of a new coating. The user is able to adjust the flow and pressure of an intensifier-style waterjet system to suit the coating being targeted.

Typical Users

Ships and Work Vessels: IMSRP, OSV, and other configurations of ocean-going assets involved in the offshore oil industry already have the necessary infrastructure in place to facilitate integration of deepwater subsea waterjet systems. An intensifier-style waterjet skid can be deployed using the same methods used to deploy an ROV asset. In the skid arrangement described here, tools would be picked from the skid, and placed in location by the ROV. This same system could be deployed at dive depths, with tools modified slightly to accommodate placement by the dive crew. Intensifier-style waterjet systems are easily configured for simultaneous operation of multiple cutting tools and multiple on-off cycles from a single system.

Platform Operators: In addition to deploying a deepwater subsea intensifier-style waterjet system for tasks such as cleaning of steering or control fins, a production or drill platform may find many surface applications in support of daily operations. These applications may include cutting (safely) in support of infrastructure repair, removal of rust-scale and coatings in preparation for new coatings, and maintenance or fabrication activities that require cutting of holes, slots, and contours.

ROV as an Attachment: For applications that require only light-duty, intermittent cutting operations, a subsea waterjet intensifier system may be adapted to be carried directly by an ROV. In the typical case, the ROV would power the intensifier from its own hydraulic system.

Salvage Operators: For salvage operators, the deepwater subsea waterjet system could be deployed for use either by divers, or by an ROV asset. The safety advantage (discussed in Subsea Waterjet Technology section) alone provides reason for salvage operators to look closely at the possibility of integrating a subsea waterjet skid into their routine operations. Flexibility to cut, clean, remove coatings, and deploy independent of depth makes this a versatile tool.

Marine Research: The versatility of a deepwater subsea waterjet system offers the opportunity to provide salvage support, removal of marine growths and coatings, and on-the-spot fabrication capabilities with one system. It is expected that the research community will help to drive advancements in both the extension of waterjet technology into deepwater environments, and into new areas of application.

Conclusion

Waterjet technology has been extended into the deepwater subsea space during the past year. Inclusion of an intensifier-style subsea waterjet system in the collection of emergency response assets will give another option for cutting, salvage, and conduct of rapid de-mobilization operations. Application of this technology in deepwater environments is in the early stages, but the underlying technology has been proven to be effective.

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