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Application of pre mixed abrasive water jet for maintenance of oil and gas ducts

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ABSTRACT: A review of general principles of the application of pre mixed abrasive water jet is also discussed, and that is widely used in different fields of the modern industry. Technical applications of ultra high pressure abrasive water jet are used with success for cutting steel ducts, even when these are reinforced with fibber systems or internal protection. The steel and reinforced elements can also be cut simultaneously with concrete structures. The use of tools specially developed to actuate in surface work locations and for cutting through walls ensure the success of this job. The new technology is an athermic system that does not generate heat, scrap, or gas, and this can be favorable for the stability of the base metal grains, as it is known that great energy can promote an adverse growth of these grains when temperature gets close to 1,038° C. The base metal grain growth is harmful as it weakens the metal that needs to be repaired. In this process, the elimination of the danger of an explosion results in better safety conditions, even though safety remains as a critical issue in the subsequent welding of the new segment. In this case, the effective use of the pre mixture abrasive water jet may provide better quality welding and greater safety for the new duct segment.

1 INTRODUCTION

1.1 *Historical review*

A hundred years ago, the first investigations about the use of water jet as a tool were performed by a group of mining engineers. In those trial investigations, the energy of a water jet was not only used to disintegrate soft rocks and coal, but also as a mean of transportation, as the excavated material was transported in a fluid state as slurry.

Since then, a series of works have been developed in several countries to utilize water jet to cut materials in the industry. Since the seventies, applications of this process have grown. Nowadays in Europe around 1,200 advanced shops use this water jet cutting system for a wide range of applications.

1.2 *General Aspects*

Ducts are one of the most trustful and secure means to transport fuels such as oil and gas. However, during their useful life they develop defects that may affect the transport structure. Among them, the reduction of wall thickness caused by corrosion is one of the major maintenance problems that can affect the duct structure. This problem appears either in land or underwater ducts.

A significant example of the damage potential of such duct defects is the recent environmental disaster at Guanabara Bay, Rio de Janeiro, as a failed fuel duct caused an oil spill that could be avoided.

With the evolution of environmental protection laws and the growth of systems of oil and gas transportation lines worldwide, the evaluation of new corrosion resistance standards has acquired great importance.

Because of economical and ecological reasons, operators of fuel transport lines must take the necessary measures to avoid duct failures that lead to product leaks, disruption to their productive schedule and above all, serious damages to the environment.

Accidents prevention represents considerable savings of resources as it also helps to protect lives, to improve corporate image, to avoid material damages and to protect the environment.

To avoid these accidents, transport lines must be periodically inspected, with subsequent structural resistance analysis of corroded duct elements.

The results of the structural evaluation of corroded ducts should provide enough data to continue with the transport operations or to make a repair decision. An adequate follow up schedule should be implemented to ensure safe duct operation until the repair is completed.

Generally, inspections are performed with the use of an instrumented "pig" or an ultrasonic scanning device that can detect a variety of defects caused by corrosion. Once the exact location is identified, the cutting operation is scheduled and the regular procedure is to freeze the liquid flow within the duct. At a safe distance from the location, a pumping truck removes the oil from the duct section that will be replaced.

Figure 1 displays an ultrasonic inspection apparatus that is normally used in Brazil by Petrobras-Petróleo Brasileiro S/A.

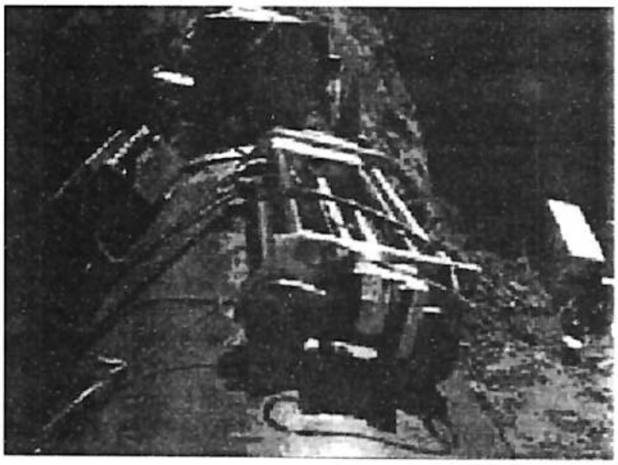

Figure 1. Ultra-sound inspection system. Source:PETROBRAS.

This duct is cleaned and once all the safety measures are implemented, it is possible to start the cutting process utilizing ultra high pressure pre-mixed abrasive water jet without risks to the integrity of workers and materials that are there. As this operation is a non-thermic process, it does not generate sparks or high temperatures that could cause an explosion.

Once the corroded section is replaced and as the line still remains frozen, the new part is then safely welded into position (Bueno, 1999).

2 GENERATION OF PRE MIXED ABRASIVE WATERJET

There are two different systems to generate abrasive water jets, the bypass and the direct pumping system. There is a sketch of both systems in figure 2.

Despite the different generation mechanisms, the most important process feature of these systems is the pressure range. In the bypass system the pressure is limited to 200 MPa; whereas direct pumping systems can operate at pressures up to 350 MPa.

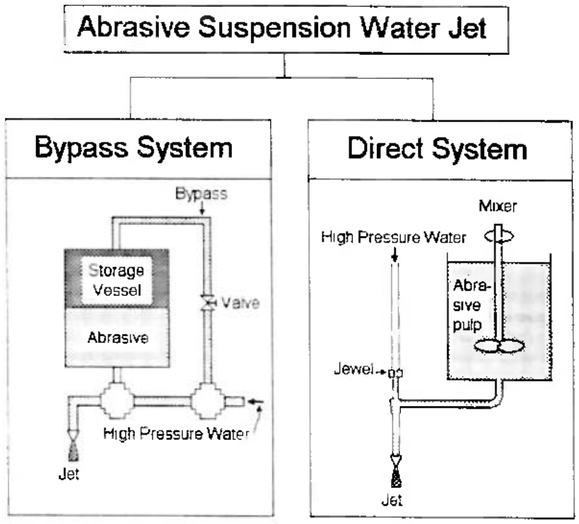

Figure 2. System of generation of suspension abrasive water jet.

Table 1 includes some data collected by Momber & Kovacevic (1998) regarding technical characteristics of the generation of suspension abrasive water jets.

In the bypass system, part of the water volume flow is used to bring the abrasive material out of the storage vessel and to mix it back into the main water-flow line.

Table 1. Results of the laboratory assaying with abrasive suspension water jet.

Reference	Pump pressure (Mpa)	Abrasive flow rate (g/s)	Slurry concentration (%)	Abrasive-grain size (µm)	Focus ϕ (mm)
		BYPASS SYSTEM			
Anerson (1992)	28.5	108	-	-	2.8-4.8
Bloomfield & Yeomans (1991)	35-69	2.8-173	12	-	0.3-2.8
Brandt et al (1994)	25-200	8.3-50	-	45-250	0.5-0.7
Guo et al. (1993)	-	-	15	#30-#100*	1.5-2.3
Laurinat et al. (1992)	18	8.3-83	-	180-710	1.5-2.4
Liu & Ciu (1988)	2-9	50	-	630	2.2
Liu et al. (1992)	10-35	3.7-142	1.5-36	-	1.36
Shimizu & Wu (1994)	20	-	18-24	75-212	1.0
Walters & Saunders (1991)	15-69	28.3	-	150-500	1.0
Yazici &Summers (1989)	21-35	20-150	-	300-1250	2.0-2.8
You et al. (1993)	35	33-117	13-17	#28-#80*	-
		DIRECT PUMPING SYSTEM			
Hashish (1991)	104-345	1.0-11	6-48	#80-#220*	0.23
Hollinger et al. (1989)**	52-104	1.2-1.7	10	53-106	0.1-0.3

* Mesh designation ** Polymer addition apud Momber & Kovacevic (1998)

The generic system design includes a plunger pump, high pressure abrasive storage tank, bypass line and abrasive hopper.

The direct system used for our tests adapted a conventional Omax water jet system and delivered an agitated slurry into the feeding of the mixture tube, without air and using the high pressure of the jewel as an accessory feeding of water.

3 PREPARING THE ABRASIVE SUSPENSION OF THE WATER JET CUTTING SYSTEM

An adapted container was used to prepare the abrasive suspension. This container was a cylindrical vessel with a mixer attached to maintain a reasonably homogenous concentration.

Measured quantities of abrasive provided 5%, 10% and 15% slurry concentrations. A plastic tube connected to the bottom of the container transported the abrasive suspension to the feeding line of the OMAX 2652A system. Thus, only water and abrasive with no air was fed into the cutting system, and characterizes a pre-mixed abrasive water cutting system.

In figure 3 displays the laboratory apparatus used to make the pre-mixed water jet.

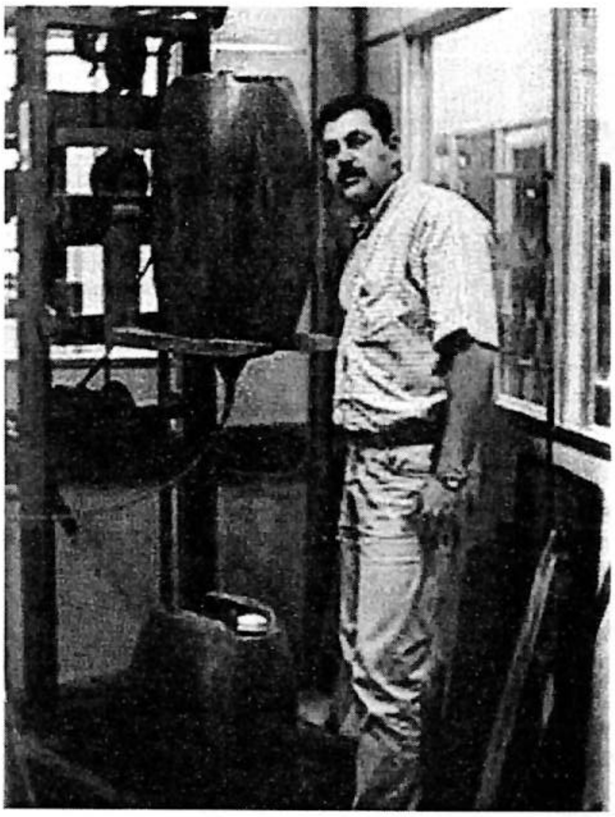

Figure 3. The apparatus used for the pre mixed water jet.

4 TARGET MATERIAL OF DUCTS

The target material of standard ducts for the oil industry are construction steel tubes whose diameter ranges from 160 mm to 660 mm with wall thickness ranging from 8 mm for small diameter piping to more than 25 mm for larger diameters.

Duct steel specifications are standardized by API - Association of Petroleum Institute - and some tubes made of this material were provided by Petrobras, both new and used samples, for laboratory testing purposes.

Our aim is to determine technical procedures as guidelines for a future development of an adequate equipment for the maintenance, recovery, and replacement of worn out or corroded duct sections in fuel transportation systems.

Current cold mechanical cutting system in use, Figure 4, after Bueno (1999).

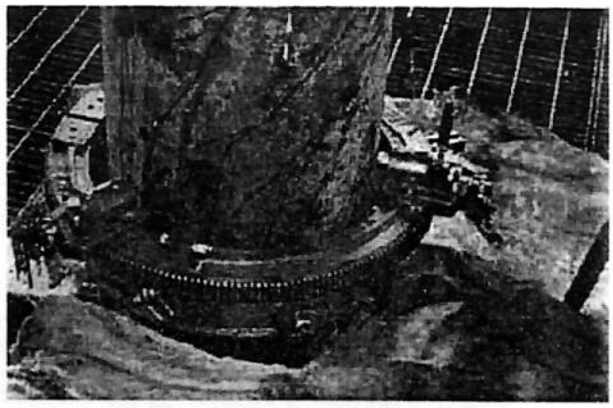

Figure 4. Cold mechanical cut now utilized.

Evaluation of the duct structure can be performed by indirect physical methods of transmission waves.

Problematic segments can be identified by ordinary scheduled inspections, and corrective measures taken whenever necesary.

5 LABORATORY TEST RESULTS

Several laboratory tests were performed with different abrasive suspension concentration, as previously mentioned, using a 200 mm diameter duct, and approximately 10 mm wall thickness..

First test was performed with the conventional Omax water, abrasive and air system, using quality 5, or the lowest traverse velocity of about 1 mm/s. This cutting operation was a success, with about 33 wiggles and no problems. Two cuts were made in the duct. The first was in normal to the diametric direction with a length of 100 mm. The other cut was 10 mm away from the first cut, also with the same length in diametral direction. Figure 5 (below) shows this test.

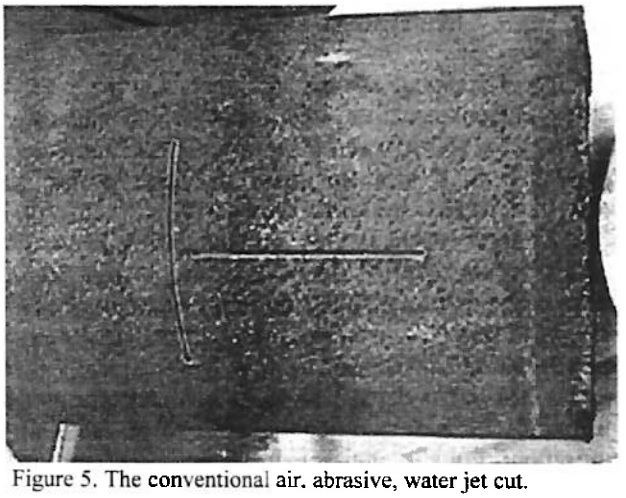

Figure 5. The conventional air, abrasive, water jet cut.

Figure 6 displays one of the three tests in which at this time it was not possible to completely cut through the duct wall thickness. There were some difficulties to obtain good pulp homogenization for the cutting operation to be successful.

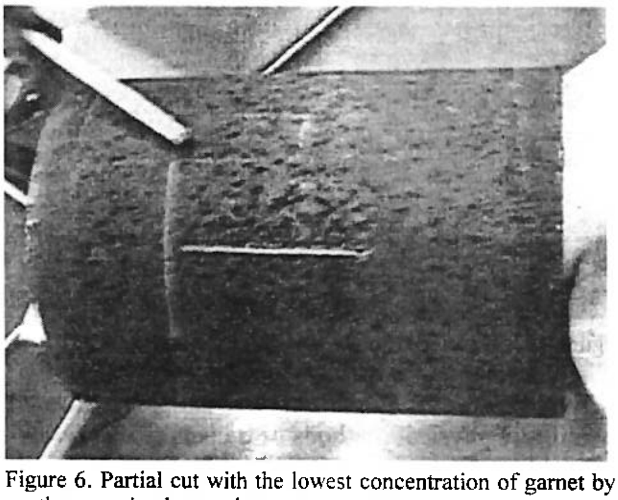

Figure 6. Partial cut with the lowest concentration of garnet by the pre mixed water jet.

6 MAIN CONCLUSIONS

These first laboratory tests demonstrated that it is possible to cut steel ducts with abrasive pre-mixed water jet without problems. More than one pass was necessary to cut the duct. The pulp feeding system needs further developments but there is improvement potential to achieve full cuts with a single pass.

Another procedure to achieve the same goal is to reduce the nozzle's traverse velocity, which was about 1 mm/s at this time.

Other noticeable aspect was an increase in water temperature during the pre-mixed water jet operation, but within a limited range that will not affect the growth of metal grains. The new procedure will allow cutting operations of metallic ducts without the excessive heat generation noticed in conventional cutting technology (figure 4).

The grains from the base metal maintain their stability after the water jet cutting operation, and display better performance during the welding the new duct section.

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