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OVERVIEW OF CLEANING AND INSPECTION TECHNIQUES EMPLOYED IN UNDERWATER ENVIRONMENT

Lucas Cruz da Silva[1] - lucas.cs@fieb.org.br
Everton Sousa Cerqueira[1] - everton.cerqueira@fieb.org.br
Bruno Schettini Soares Pereira[1] - bruno.pereira@fieb.org.br
Henrique Souza Baqueiro dos Santos[1] - henrique.santos@fieb.org.br
Luciana Moreno Borges[1] - luciana.borges@fbest.org.br
Rômulo Guedes Cerqueira[1] - romulo.cerqueira@fieb.org.br
[1]Senai CIMATEC, Brazilian Institute of Robotics - Salvador, BA, Brazil

Abstract:

The Oil & Gas Industry undertakes installation and maintenance of underwater ocean assets in order to extract natural resources from seabed, with all sorts of structures such as oil pipes, risers, valves and vessels. These facilities often are breeding places for marine growth, and this biofouling represents a barrier for the regular inspection of these structures. In this context, this work presents an overview of cleaning and inspection technologies employed in underwater ocean environment. They are applicable for a variety of components in asset infrastructure. In the cleaning category, methods for preventive treatment, biocide action and active cleaning are shown. In the inspection category, the described methods contain different approaches for 3D reconstruction of a scenario, based on arrangement of cameras, laser and light sources.

Keywords: Underwater Cleaning; Underwater Inspection

INTRODUCTION

Improvement on underwater operation is a constant matter of interest to the oil & gas industry. As newer locations for natural resources have continuously being found deeper in oceans (e.g. Brazil's pre-salt), so this segment in industry is increasingly reliant on robotic technology to run operations in this environment.

Several types of components in infrastructure populate the assets in underwater ocean environment like oil pipes, valves, risers and vessels. Within years after installation, it is usual to have these elements in the facility influenced by the environmental ecology, such as settlement of marine growth (biofouling) on the asset infrastructure.

Biofouling or marine growth are colonies of opportunistic marine organisms which adhere man-made structures on the sea. They are defined as opportunistic organism because they do not inhabit the seabed on the structure localization [1]. Such organisms can increase structure weigh by 6 to 12%, with the additional problem of structure corrosion due to bacteria action [2, 3].

Therefore, the asset's components need to be regularly inspected in order to assure their integrity, and the presence of biofouling imposes a physical and/or visual barrier to the inspection task.

This work presents featured techniques in market used for cleaning and inspection of assets in underwater environment. Cleaning techniques shown involve aspects ranging from prevention and treatment to active cleaning in many types of underwater structures. The inspection techniques focus on visual methods for 3D reconstruction, which is the main target of inspection in assets.

CLEANING AND PREVENTING TREATMENT TECHNIQUES

Ultrasonic

Cleaning surfaces with ultrasonic method consists in emitting multiple bursts of ultrasonic waves in different frequencies simultaneously. These waves use the surrounding media for propagation, resulting in mechanical waves (the same way as in sound waves) therefore producing a pattern of positive and negative pressures. This alternating pattern creates microscopic bubbles of water vapor during periods of negative pressure and then implodes them periods of positive pressure. The implosion creates a micro-jet action that cleans the underwater surface, killing microorganisms which adhere to the surface and produce biofilm, the future home for biofouling [4]. This way, the cleaning action aims to eradicate local marine growth by acting on the basic level of the food chain.

There are currently several commercial ultrasonic kits available for boats on the market. Using this technology, after months in the water, the surface will present only a very light coating of slime that can be easily wiped off.

Ultrasonic cleaning is an environmental friendly process as it does not make use of any chemical reagent. Also, it has no effect on the treated surface (transducers are glued to the hull). However, it is not effective for all types of biofouling.

Antifouling Coating

Antifouling coatings are employed in prevention and minimization of settlement of biofouling on surfaces working in underwater environment. Just as the Ultrasonic approach, antifouling coating is rather a preventive method of avoiding marine growth, rather than a cleaning one. This method is divided into two main categories: biocidal and biocide-free coatings [5].

Biocidal coatings are made up of chemicals which inhibit larval settlement and attachment to the surface. The methods considered biocidal-free can be categorized into fouling release coatings and mechanically resistant coatings. Fouling-release coatings, when applied to a surface, reduce the strength of biofouling adhesion, so no colonies will settle. The latter are designed to be resistant to abrasive forces given that they are designed to be mechanically cleaned. It is recommended to use biocidal paints in a medium submitted to constant laminar flow of water, since this is the method employed to spread the biocide agents.

Tributyltin or TBT was a biocide adopted since the 1970's because of its excellent anti-fouling properties, preventing the growth of algae, barnacles and other marine organisms. Since its ban in 2008, alternative to toxic TBT-based coatings increased tremendously [6]. Among all the antifouling paints in use, those containing copper are the most commonly used following the ban of organotin biocides due to non-target environmental effects.

Notwithstanding, there are still some barriers that slows down the adoption of antifouling coatings. Prior to the ban, TBT-based coatings dominated the market, and as of today it is not clear whether the new biocidal or foul-release coatings will strive to be the best approach to surface coating [6]. Increased price of non TBT-based paints, the possible need to re-coat more often and its technical maturity are also factors that have to be taken into account when adopting this approach.

Encapsulation

Encapsulation techniques are low cost and simple. It is based on depriving biofouling organisms of essential resources (light, air, food). However, there is the environmental inadequacy of the biofouling material and acids left to the surrounding medium and it is not yet known the effect of enveloping in different coating types.

In addition, this technique may be too slow to cause mortality where the time frames are short, such as visiting vessels which usually stay less than 48 h. Mortality can be accelerated through the addition of chemical agents to the encapsulated region.

Considering a general hull area of 150 meters in length, encapsulation period may take at least 17 hours to 14 days with those minimum and maximum times dependent on whether an oxygen scavenging or biocidal chemical is used. The recommended procedure is to apply acetic acid with 5% concentration for 48 hours [5]. Encapsulation can be applied to convex underwater surfaces (vessels), whereas on concave confined surfaces, like tunnels, other methods should be considered.

Heat Treatment

Surface heat treatment consists in applying thermal shock (70° C) using sea water to the biofouling attached to the surface in a sealed area, or also by using adapted oxy-gasoline or laser cutting torch otherwise. The thermal shock will lead to the death of organisms population, which will remain softly attached to the surface but since the biological activity will cease, their remains will be released within 2-4 weeks due to water movement. This method kills algae and spores, which delays the process of regrowth. It is appropriate for light to moderate fouled surfaces [4].

Heat treatment may be considered environmental friendly in comparison to the use of biocides, although there may be restrictions to the volume of heated water that can be discharged into the surrounding marine environment. The treatment has potential to be used as a preventive measure, although applications at regular intervals may have undesirable consequences to antifouling paints efficacy [5]. Also, there is no commercial solution available to large surface treatment such as hulls in vessels [5].

Suction

This technology uses a vacuum pump with a filtration system. It pulls out the biofouling from surfaces by negative pressure provided by the pump. The filtration system separates the remains from the surrounding medium. It is able to remove 80% of soft marine growth [4] but its use is not recommended for firmly attached organisms such as barnacles, tube worms, and cementing bivalves. In addition to that, it is common to have the nozzle or the suction hose clogged by the removed material. There is commercial availability for this kind of technique.

Ultraviolet irradiation

UV radiation is a non-chemical alternative to control biofouling. However, UV radiation itself does not have an expressive impact on biofilm control. In addition, further investigation is needed in order to optimize all the parameters (wavelengths, doses, continuous or in cycle exposure)[4].

According to Dobrestov *et al.*[7], UV radiation directly controls the development of micro- and macro biofouling communities. This is achieved by inhibition of recruitment and growth of more sensitive species and promoting growth of resistant species, altering the microbial community [7].

Water Jets

Water jets are becoming widely used in underwater cleaning due to its easy to control pressure, distance and attack angle. Also, jet nozzles have been developed to enable effective cleaning of surfaces in underwater environment [4], with several suppliers offering commercial solutions. Because the equipment usually works with higher pressures, they demand high power from the facilities where they are installed.

Currently, most water jet systems can be found classified into two major categories: cavitation and non-cavitation systems. Cavitation systems use high pressure water combined with nozzles designed to produce large pressure differential with respect to the environment. The transition from high to low pressure under the same temperature makes the water in surrounding medium to transform into microscopic water gas bubbles. These bubbles collapse upon touching a surface, producing micro water jets whose energy wipes the content on the surface, providing a cleaning action. Lower water pressure (70-150 bar) can be used to produce high pressure (15 x 10^4 bar) at the treatment point.

Non-cavitation systems use regular nozzles and count on the energy contained in the water itself, thus requiring a high operating pressure (500-1000 bar) to achieve the same cleaning effectiveness as cavitation systems [4].

High pressure water jets can damage or even cut the material, so safe pressure values, distances and attack angles for the specific material must be known prior to the cleaning.

Brush

Brush-based technologies are the most used approach in underwater cleaning [5], with high productivity compared to others (200 m^2/h up to 1000 m^2/h) [4].

Rotary brushes apply mechanical and frictional forces, so they are part of a very abrasive method which can damage the original surface. Brushes are also unable to capture the cleaning waste, which can contain residues of toxic materials [4], therefore having to be associated with other methods for this matter, such as suction.

Brushes are versatile, being handled by divers, controlled by robotic arms or coupled in Remoted Operated Vehicles (ROVs). A variety of shapes and bristles can be found in the market.

3D VISUAL INSPECTION TECHNIQUES

Sensors for three-dimensional measurement can be categorized into three classes depending on the measuring method: triangulation, time of flight and modulation. A sensor can belong to more than one class, meaning that it uses different methods or a combination of them to obtain three-dimensional data [8].

The task of registering optical images in ocean environment can be very difficult, since it has high opacity [9]. The effects of scattering and absorption reduce the quality of images recorded underwater. Forward scatter results in blurred images with low contrast due to small angle deflection, while backscatter occurs when the camera reflects the emitted light from a light source prior to it reaches the target.

With longer distances to the target, larger volumes of seawater increasingly reinforce these effects. As images need light to be recorded, natural light can be used in shallow depths in seawater, but it becomes attenuated in higher depths. Therefore, artificial lighting must be provided in strategic locations related to the target [10].

From the illumination type point of view, underwater visual systems can be, generally speaking, roughly classified as passive or active. Passive systems rely on illumination provided by an external light source, be it natural or artificial, to work properly. The external light source can be a feature from another device participating in the inspection task. Active systems, on the other hand, bear sensors capable of providing illumination by themselves, without depending on the environment to run the inspection task.

Laser Line Scanning (LLS)

Laser line scanning techniques use laser beam combined with cameras to realize mapping of environments. This collection of methods seek to overcome difficulties imposed by scattering and absorption of laser in water, which invalidates traditional laser scanning methods used on dry environment based on time of flight of laser beams. This technique improves contrast and resolution beyond that offered by systems with visible light [11].

Green lasers working at 532 nm are a common solution as this wavelength have low absorption and scattering in seawater. Also, this technology is well spread in market. At the reception side, several solutions can be used, such as photomultiplier tubes (PMT), photon counters, photodiodes and cameras [8].

Structured Light

The inspection with structured light consists of three components: a camera, a projector and an object of interest [12]. The projector casts a known pattern of light onto the object of interest, with is then captured by the camera under a specific angle of view. Since the distance between the camera and the projector is known, together with the angle of view the depth of the image can be calculated by trigonometric relations.

Photometric Stereo

Photometric stereo consists in 3D reconstruction of a target object with computer vision by using different pictures taken from the same point of view, but with different illumination direction.

This technique needs only a fixed camera and a light source with different directions. By illuminating the same object in a certain direction on each take, the light source will produce a shade pattern on the object. Therefore, the distinct shade patterns for each will provide enough information to have a 3D mapping of the object. This method demands prior knowledge on geometry of the testing scenario (the light sources are considered punctual and reasonable distant) and the the surface reflects incident light [13].

Stereo Vision

This method uses more than one camera to compute 3D data. The cameras are placed with known displacement, and the same scene captured by the cameras has its points analyzed and compared with trigonometric relations using triangulation. This way, depth on an image can be inferred. [14]

Although this technique can be used by assembling independent cameras in one frame, there are out-of-shelf products that have the cameras mounted with known displacement, reducing the effort in displacement measurement and camera calibration. This method relies heavily on efficiency in the algorithms used in 3D reconstruction.

CONCLUSION

This work presented a review on methods for cleaning and inspection enabling suitable for underwater environment endeavors. Some of the cleaning techniques are environmental friendly, but are not suitable for automatic operation (as is the case with encapsulation and heat treatment), whereas others require active effort with the advantage of portability (water jets, suction and brush).

The 3D visual methods can be employed with a variety of materials, such as lasers, cameras, combination of both or use of intelligent lighting, all with advanced technical maturity. The choice for any of them is directly related to geometric constraints and cost.

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