Innovative Robotic Solutions for the Survey and Certification of Ships and Mobile Offshore Units

Peter Weiss, Cybernetix, Marseille/France peter.weiss@cybernetix.fr
Fivos Andritsos, JRC**,** Ispra/Italy fivos.andritsos@jrc.it
Frédéric Schom, Cybernetix**,** Marseille/France frederic.schom@cybernetix.fr
Alain Fidani, Cybernetix**,** Marseille/France alain.fidani@cybernetix.fr

Abstract

Accidents on offshore oil production facilities and oil tankers in the last decade have drawn security, survey and certification of such equipment in the limelight. But most of these procedures require a high effort in terms of time and personnel. Robots will be a solution to carry out these procedures more efficiently. The use of underwater robots in this field will furthermore open up new possibilities to survey and certify ships or oil production facilities on sea without the need of a dry-dock (which is highly relevant for large offshore production facilities that need to last years on sea). This paper will present some applications of robotic systems that offer a solution for the survey of ship's hulls and the control of the state of large anchor chains. The application of such systems can lead to new possibilities of survey for certification assuring the security of these facilities and ships on sea.

1. Introduction:

Maritime disasters in the last decade have put once more in evidence the importance of periodic inspection and the quality of such assessment. The certification of vessels and large offshore facilities like FPSOs (Floating, Production, Storage & Offloading) are nowadays done mostly by human inspectors. But this task becomes more difficult for the inspection for the underwater sections or, in the case of double hull tankers, the ballast tanks. While in some cases divers and Remote Operated Vehicles (ROV) can be used, in other cases an inspection is simply impossible.

This paper will present three recent projects that address at the issue of inspection, survey and certification of such equipment. Nowadays mainly two means of survey are used: the Non-Destructive Testing (NDT) with for example ultrasonic sensors, to measure the thickness of steel plates, and the visual inspection to detect cracks and evaluate the state of the coating (Fig.1). The three robotic systems presented in this paper bear the possibility to undertake such measurements and evaluation for the certification of offshore facilities.

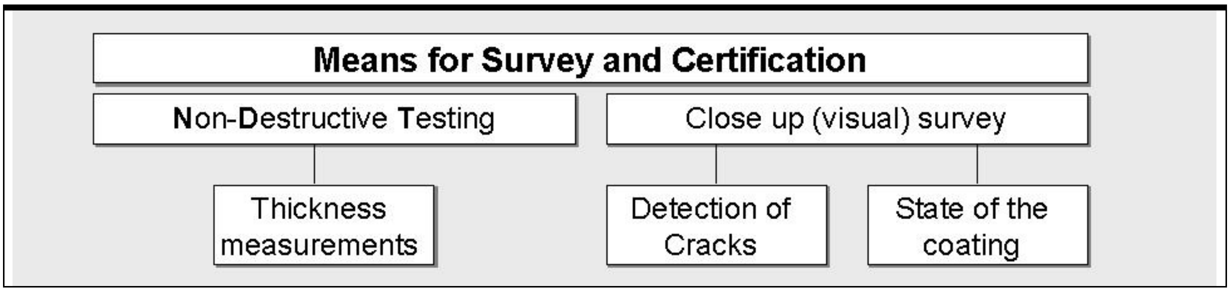

Fig.1: Means of survey and certification

2. Robots for Survey and Certification

Robots can be used for the survey and certification of large offshore structures or ships. While some of these systems can replace the human diver for the inspection work, some others even open up new possibilities of survey. The following sections will present three examples of robots in this field: The OCTOPUS hull crawler for the inspection of the outer hull of these facilities, the ICARE chain climbing robot for the inspection of anchor lines and the ROTIS Remote Operated Vehicle (ROV) for the inspection of the inner parts of double hull tankers.

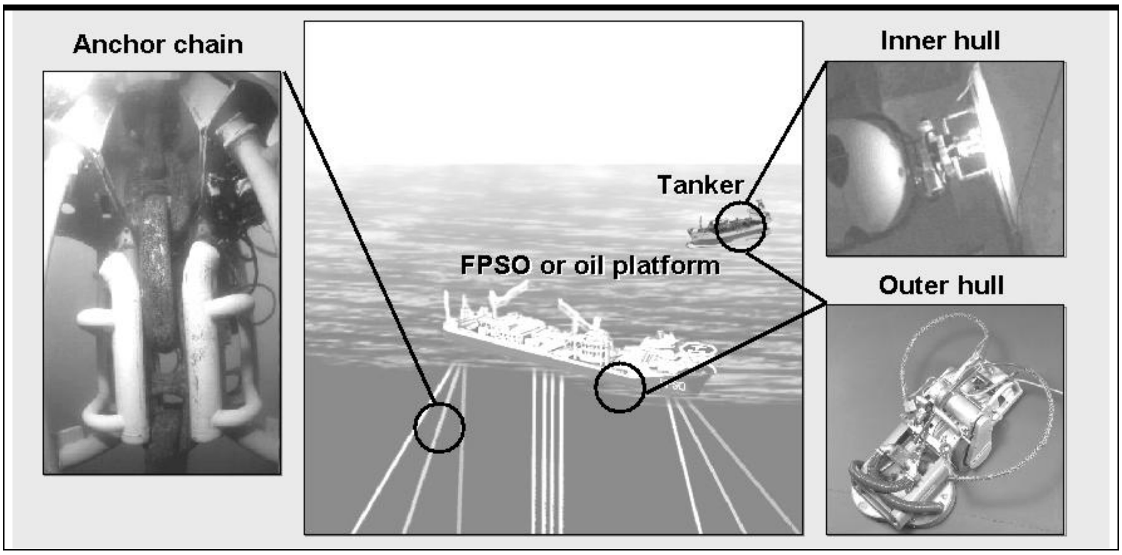

Fig.2: Possibilities for robotic inspection on offshore structures and ships. (*left*: The ICARE chain inspection robot; *top right*: the ROTIS inspection ROV, photo courtesy JRC; *bottom right*: the OCTOPUS hull crawler)

2.1. The OCTOPUS hull-crawler for inspection and thickness measurements

One robot that addresses to the issue of the inspection of the outer hull of ships and other structures like FPSOs is the OCTOPUS. The OCTOPUS is an automatic hull crawler equipped with permanent magnets enabling this vehicle to crawl along vertical surfaces. The carrier vehicle was at the origin developed for the cleaning of ships hulls by High Pressure (HP) water blasting in the dry dock. The consortium working on this project was I.CO.S.R.L (I), R.G.I Resource Group Integrator (I), LISNAVE Shiprepair (P), UNINOVA (P) and CYBERNETIX (F), *Weiss et al. (2003)*.

Several evolutions of this robot were build since this first approach like the OCTOPUS for painting (also the PASOC project) and an underwater version of the OCTOPUS crawler. Especially the last version is of high interest for the subject of inspection of ships or offshore facilities.

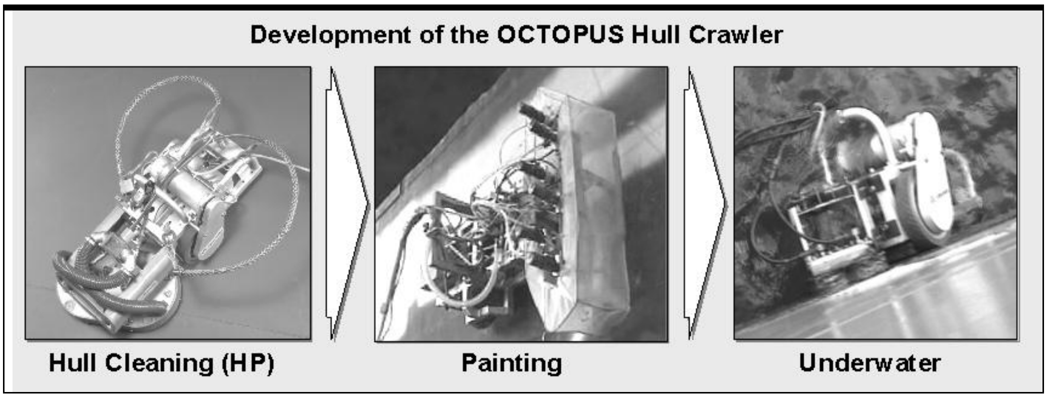

Fig.3: The different applications of the OCTOPUS crawler

In its original version the OCTOPUS was dedicated for the washing and blasting of large surfaces like the ship's hull, *Weiss et al (2003)*. The surfaces that can be treated can be either vertical, inclined or horizontal. The capabilities of the vehicle allow a treatment of approximately 80% of the complete surface of a ships hull (problems arise with small angles like for example at the bow and the stern parts). For the washing of the surfaces an efficiency of approximately 150 m2/h was reached and for the blasting 90 m2/h with a linear speed of 0.15 m/s. For movements without blasting, OCTOPUS reaches speeds up to 0.30 m/s. The blasting is executed with Ultra High Pressure water jetting that reaches a pressure up to 2500bar. One of the advantages of the system is the fact that the used waters and thus the waste, are recovered by the system. This makes OCTOPUS a very environment friendly tool compared to the techniques used nowadays that imply pollution and overspray. The same can be stated for the noise pollution: Traditional hand-carried water guns emit noise levels up to 115 dB, OCTOPUS came in at 65 dB which also represents a significant ergonomic and ecological aspect for the workers and the environment.

Since the official end of the OCTOPUS project, further applications for the crawler were developed. The idea was always to keep the robot as modular as possible. One crawler can be equipped with different tools and can thus be used for different applications. While the first OCTOPUS was only for the use in the dry dock, a underwater version was developed since then. Fig.4 shows different underwater applications of the robot.

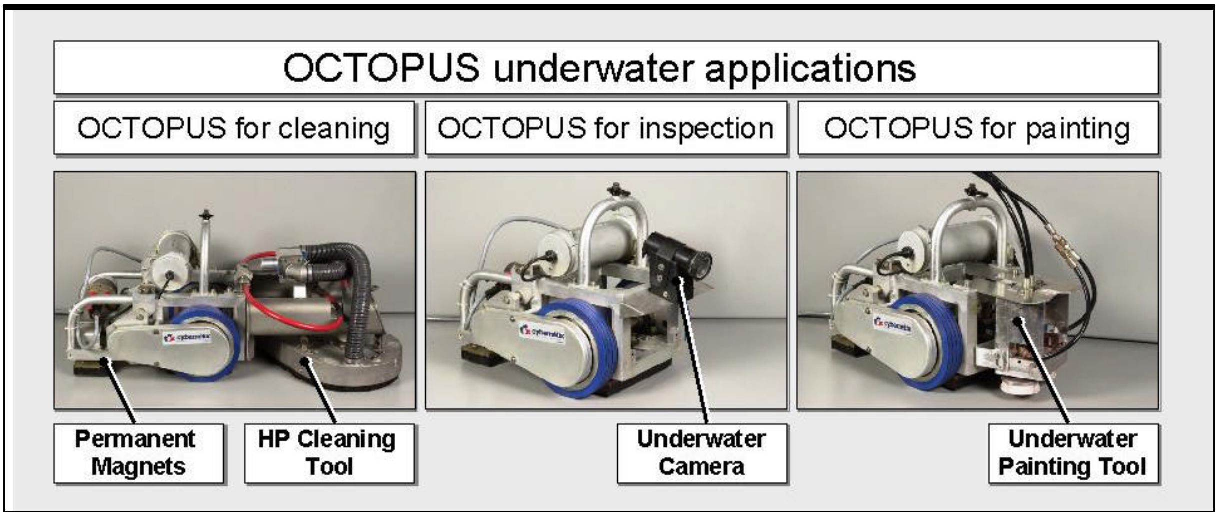

Fig.4: The modular OCTOPUS crawler with its underwater tools.

For the inspection and certification of ships and offshore facilities, the camera version is of high interest. It can be necessary to first clean the surface before doing the inspection. The HP Blasting tool can here be replaced by a system of brushes for underwater applications. One of the main arguments for this is the fact that the equipment for the HP blasting is too large and inflexible for this application. Furthermore the force of blasting is more adapted to the removal of the coating, which is not needed for the inspection. Electrically driven brushes on the other side need a relatively small cable for the power supply and are in this application sufficient, since only marine growth is to be removed, *Chardard (2003).*

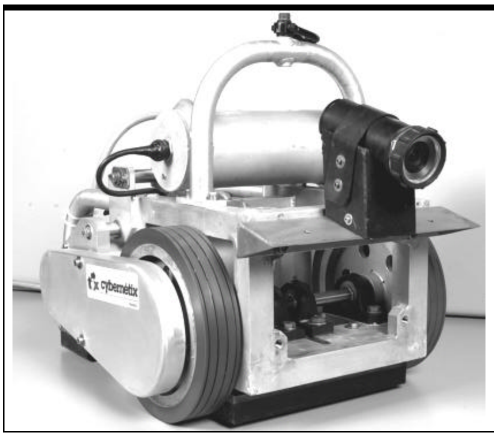

Fig.5: OCTOPUS for underwater Inspection equipped with camera

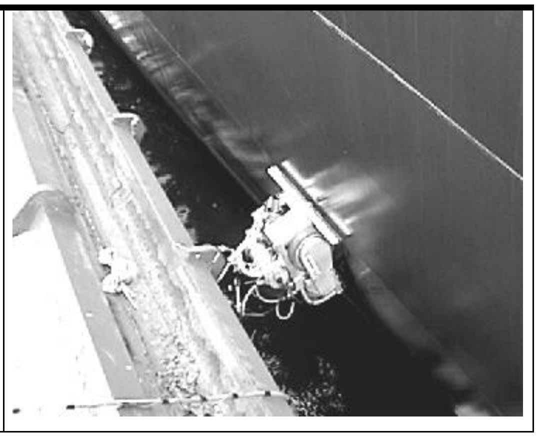

Fig.6: OCTOPUS for underwater inspection during trials on a cruise ship

Experiments with the underwater camera system were executed on a cruise ship in Marseille harbour. While the results were promising, one critical point is clearly the visibility in the water which limits the vision field to the area in front of the vehicle. (This is worsened by the fact that waters in harbours are normally not very clean, so the system is confronted with the worst situation imaginable.) The positioning of the vehicle is a further challenge for the execution of a hulls survey. The steel plates where damages were found must be located correctly in order to foresee replacement or further inspections. Therefore the inspector must exactly know where the vehicle is at the moment of the survey.

The procedures for the inspection of a ships structural and equipment requirements foresee that it may be necessary to check the underwater portions of a ship in order to evaluate its safety, *Paris MOU (2000).* A typical intervention scenario for such an inspection by a underwater OCTOPUS is shown in Fig.7: The robots crawls along the sub-sea hull of the tanker while the inspection crew is following the robot by a small support vessel to avoid long cable lines.

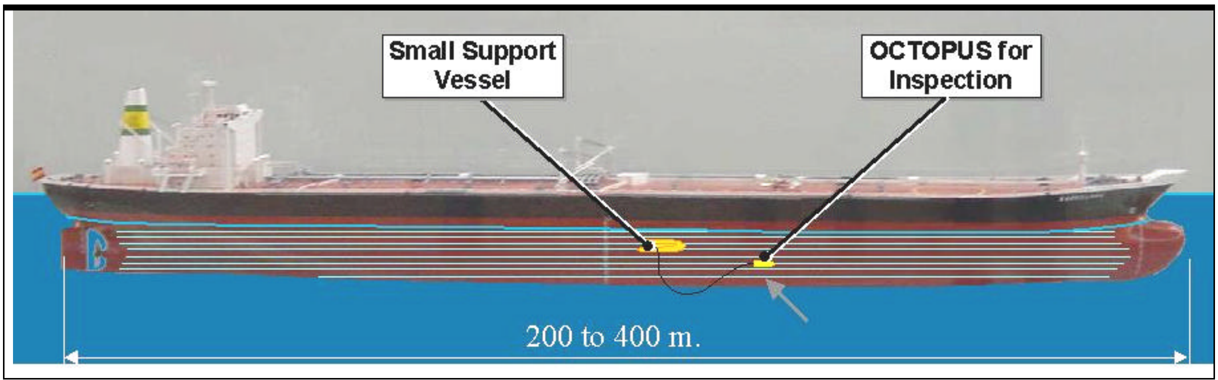

Fig.7: Inspection of the outer hull of a tanker.

Thickness measurements of the hulls walls are a essential part of such inspections, since this data informs about the seaworthiness of the ship. Such data is in most cases acquired through non-destructive testing (NDT) with ultrasonic sensors. One of the future developments in the frame of the OCTOPUS will be to equip the robot with NDT sensors in order to enable it to take thickness measurements along the hull.

This proposed procedure, or the possibility to execute inspection while the ship is still in water, is of high interest in the case of oil platforms or FPSOs, thus structures that cannot easily be placed in a dry-dock and that need to last for years on sea.

A scenario imaginable would be, for example, to do the inspection while the ship is on its way to the dry-dock and thus preparing a planning before. This possibility would avoid long standing times in the dock, since the reparations and the necessary material can be foreseen before the arrival of the ship.

2.2. The ICARE chain climbing robot for the inspection of anchor lines

A particular application of automated inspection systems can be found on FPSOs (Floating, Production, Storage & Offloading; Permanently installed oil production vessel): These floating production facilities are fixed with mooring chain lines to the seabed. To our knowledge there does not exist any automated system so far that can be used to measure these chains, while its integrity is of high importance for the security of these facilities. Typical testing procedures include close visual inspection of the chains, enhanced representative NDT sampling and dimension checks, *IACS (1995).* In the past, incidents happened due to broken anchor lines, leading to a drift off of stockade buoys.

The ICARE system is a remote operated system developed by CYBERNETIX for surface and sub-sea cleaning and inspection of anchor chains. The robot takes pictures of each chain member that allow the inspector to check the chain for cracks and corrosion. A inspection chamber that comprises the vision system turns around each chain member in order to take frontal pictures of each member (since those are shifted by 90° each). The certification will be supported by an image processing system that analyses 12 dimensions on each chain member (see Fig.9). The so acquired data is presented on the Man-Machine-Interface to the inspector, enabling to establish a detailed report about the state of the chain. Additional measurements can either be pre-programmed or manually chosen during the process. Onshore inspection results showed an average error of 0.8% (less than 1mm) for the measurements in the case of chain sizes up to 6".

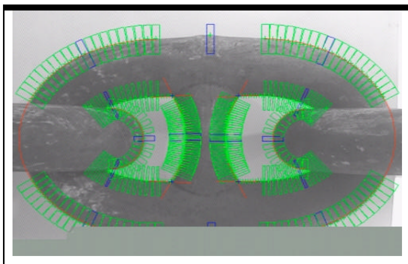

Fig.8: Still image of a chain member taken by ICARE

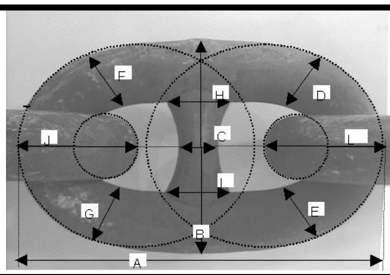

Fig.9: 12 measurements are take for each chain member

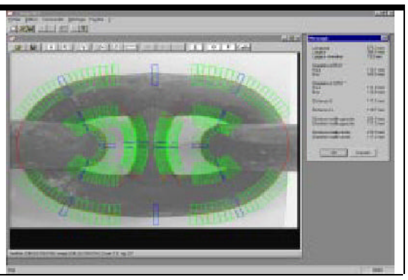

Fig.10: The Man-Machine-Interface of ICARE

The vertical displacement of the system, or the "climbing" up and down the chain, is done by a system of two claws: One claw holds the chain while the second one is displaced. When the second one closes around the chain, the first one can be displaced. The whole system is slightly buoyant in water. ICARE can be operated in stand-alone configuration or be interfaced with a Work ROV that supplies the system with hydraulic and electric power and assures the data transfer to the surface.

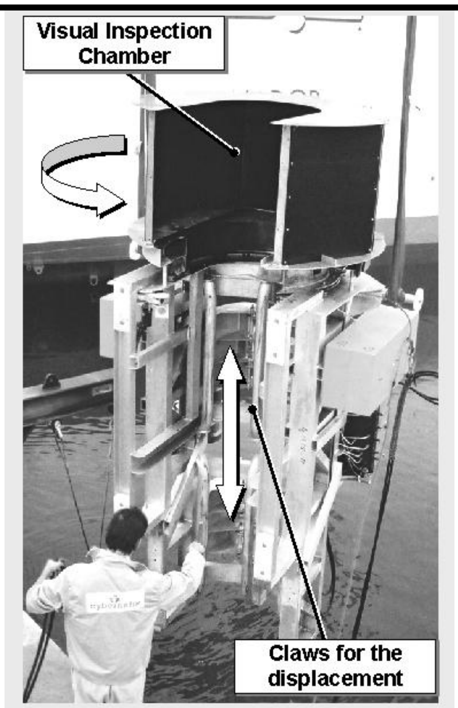

Fig.11: ICARE being lowered into the water

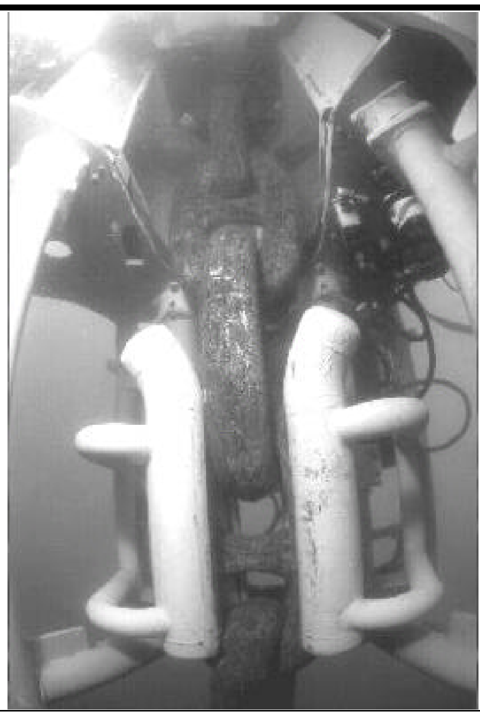

Fig.12: Underwater photograph of the ICARE climbing down the anchor line.

Like for the inspection of the outer ship hull with the OCTOPUS robot, cleaning of the anchor chain could be necessary in order to take correct measurements. A high pressure water jet system was interfaced to the ICARE for this reason, enabling to clean the chain members before the inspection.

Fig.13. and 14: Cleaning of the chain members by HP water jet

The initial prototype that was developed in 1999 was successfully tested at the CYBERNETIX facilities and lead, due to a positive feedback of potential industrial end users, to an improved industrial version of the ICARE anchor chain inspection system.

2.3. The ROTIS robot for the inspection of double hull tankers

Following to the tragedy of the PRESITGE accident in November 2002, single hull tankers were banned from the EU waters, *Andritsos-Maddalena (2003).* The introduction of double hull vessels is widely seen as appropriate mean to avoid future maritime catastrophes of this kind. However new means to inspect and monitor those vehicles must be found in order to assure maritime safety efficiently.

In the frame of the ROTIS project, a **R**emote **O**perated **T**anker **I**nspection **S**ystem was developed, based on a compact, free-floating ROV able to navigate inside the flooded ballast tanks of double hull tankers to carry out close-up visual inspection and wall thickness measurements, *Andritsos-Maddalena (2003)*. The consortium developing the ROTIS was co-ordinated by TECNOMARE (I) with ZENON (GR), ENEA (I), LLOYDS (GR), CS&A (GR), AVIN (GR), HUT (FIN) and JRC (EC) as project partners. The project was financed by the European Commission under the BRITE-EURAM framework.

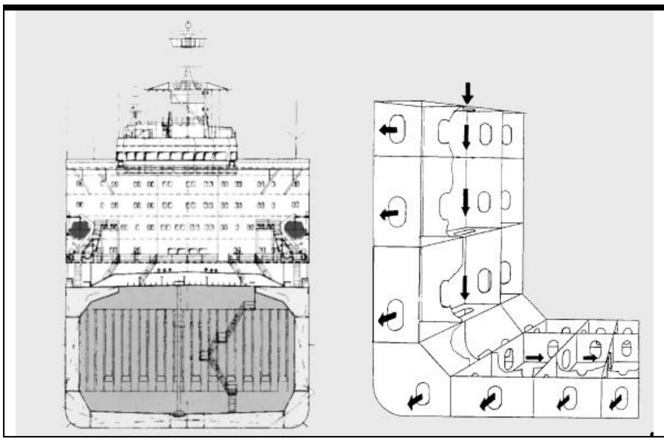

Fig.15: Ballast tanks give access to virtually all the structural parts of a double hull vessel

Fig.16: Photographs from the ballast spaces of a new build double hull tanker

Fig.15 shows the basic concept of the ROTIS system: A highly manoeuvrable, small ROV navigates through the manholes inside the ballast tanks of the ship. It is linked through a tether to an intermediate unit situated on the ship's deck, which is radio linked to a surface unit in the ship's bridge.

The ROV is equipped with a ultrasound measuring probe and a vision system allowing the operator visual inspection and thickness measurements of the vessel's walls and stiffeners. Following figures show 3D models of the ROTIS while navigating in the ballast tanks and photographs of the ROV taken in the JRC test pool during the trials. A specially designed mock-up of a double hull tanker section allowed intensive tests of the equipment at the JRC. These test confirmed the global concept of the robot especially in terms of navigation and manoeuvrability. The thickness measurements were identified as a critical aspect since it requires a stable, perpendicular docking to the walls. Suction pads were used to fix the ROV to the wall. To improve the measurement a wire-brush was installed in order to clean the surface.

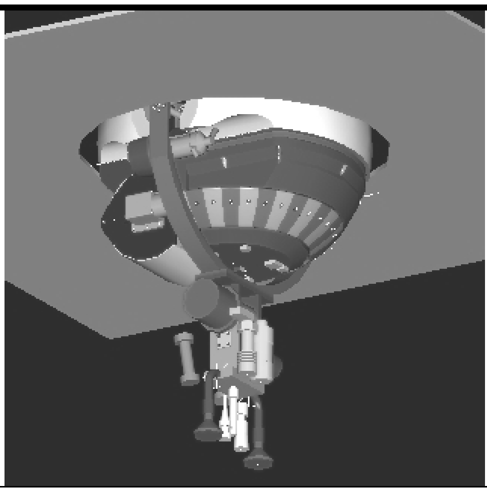

Fig.17: ROTIS passage through a 60 cm ∅ manhole

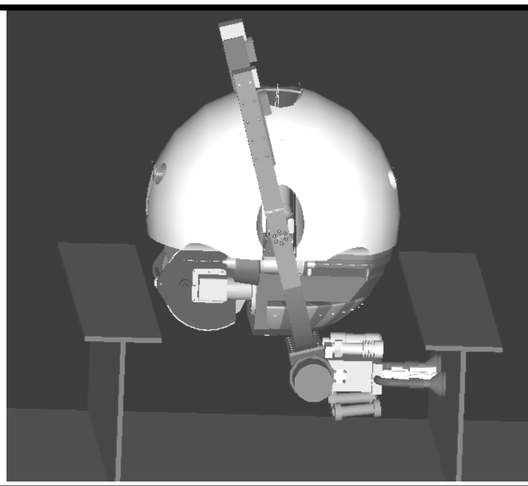

Fig.18: 3D model of ROTIS inspecting a stiffener

Fig.19: Photograph of ROTIS passing through a horizontal manhole

Fig.20: Photograph of the docked ROTIS while perform visual inspection and wall thickness measurements.

The ROTIS project confirmed the feasibility of remote operated inspection of double-hull vessels which presents the possible answer to a economic certification of those ships for the future.

3. Conclusion

The paper presented three robotic systems that could deliver an answer to the need of automated inspection of offshore facilities and ships. While these procedures are nowadays mainly executed by humans or divers, robots could be used in the future for these tasks. The advantages resulting from this are various: Robots can replace divers in this difficult work, leading to more precise and standardized measurement methods and even new possibilities to certify the security of these facilities.

Acknowledgements

The authors want to thank the members of the ROTIS consortium for their helpful input for writing this paper. ROTIS was a project financed by the European Commission under the BRITE-EURAM framework , coordinated by TECNOMARE (I) with ZENON (GR), ENEA (I), LLOYDS (GR), CS&A (GR), AVIN (GR), HUT (FIN) and the JRC (EC) as project partners.

The OCTOPUS robot was developed under the GROWTH programme of the European Commission. The project was coordinated by CYBERNETIX (F) with I.CO.S.R.L (I), R.G.I Resource Group Integrator (I), LISNAVE Shiprepair (P) and UNINOVA (P) as project partners.

References

WEISS, P.; SCHOM F.; CHARDARD Y. (2003), *Intervention of robots in shipbuilding and maintenance*, 2nd Int. EuroConference Computer and IT Applications in the Maritime Industries, Hamburg, pp.425-431

CHARDARD, Y. (2003), *Robotics in ship maintenance and inspection*, Offshore/Marine Fabrication & Conversion 2003, Singapore

Paris Memorandum of Understanding on Port State Control (2002) , adopted 9th May 2002

International Association of Classification Societies IACS (1995), Guidelines for the Survey of Offshore Mooring Chain cable in Use (No.38), 1995

ANDRITSOS, F.; MADDALENA, D. (2003), *ROTIS: Remotely operated tanker inspection system*, 8th International Marine Design Conference, Athens