<CAS/>

FP6-516561

Name: **Publishable final activity report**

Date: 2008-08-26

Editor: **Philippe Renard (BV)**

Contributors:

approved by:

Task / Deliverable Number: **D-7-1-1**

Reviewed by / Date:

Version: **1.0**

Status

Reference Number:

Version History:

Version	Issued date	Changes /comments
0.1	2008.06.13	Initial version
1.0	2008.08.26	Final version

Table of Content

1 PROJECT EXECUTION 6

1.1 PROJECT OBJECTIVES 6
1.2 CONTRACTORS INVOLVED 7
1.3 WORK PERFORMED AND END RESULTS 8
1.3.1 *Methodology* *8*
1.3.2 *Ship measurements modelling* *8*
1.3.3 *Appropriate measurement technology* *10*
1.3.4 *Assessment of ship condition* *10*
1.3.5 *Risk-based maintenance planning* *10*
1.3.6 *Demonstration in repair shipyard* *11*
1.4 DEGREE TO WHICH OBJECTIVES WERE REACHED 12
1.5 IMPACT OF THE PROJECT 12
1.5.1 *Classification societies* *12*
1.5.2 *Maritime audiences* *13*
1.5.3 *General public* *13*

2 DISSEMINATION AND USE 14

Table of Figures

FIGURE 1 RE-ENGINEERING THROUGH CAS 7
FIGURE 2 HCM CORRELATION WITH 3D VISUALISATION 8
FIGURE 3 ROBOT ON SHIP'S HULL 12

1 Project execution

1.1 Project objectives

The project was intended:

- to integrate all phases of the ship condition assessment process, achieving seamless communication between the measurements on board the ship and the use of sophisticated structural condition assessment tools.
- to build a simplified ship electronic model of the ships to be inspected. It was to be a numerical 3D model designed to collect measurements on board ships in service, then to perform all possible post-treatments from this 3D model. The 3D model was to be a neutral standard to enable exchange data between all concerned actors, mainly: Thickness Measurement Company (TMCo), Classification society and Shipowner.
- to add measurement and inspection information into the ship model. Each measurement on board would finally be associated with a specific structural element in the ship model.
- to provide the channel for integration of robots-made measurements.
- to provide a few hours after any ship's inspection a complete view of the current condition of the ship, using visualisation and virtual reality tools, thus triggering immediate requirement for repairs, instead of the weeks of delay needed with the existing process.
- to provide repair decisions and residual lifetime of the structure with modern methods of risk based maintenance modelling.
- to provide a gain in overall efficiency of ships repairs and consequently in ships safety as a consequence of the integration of the process.

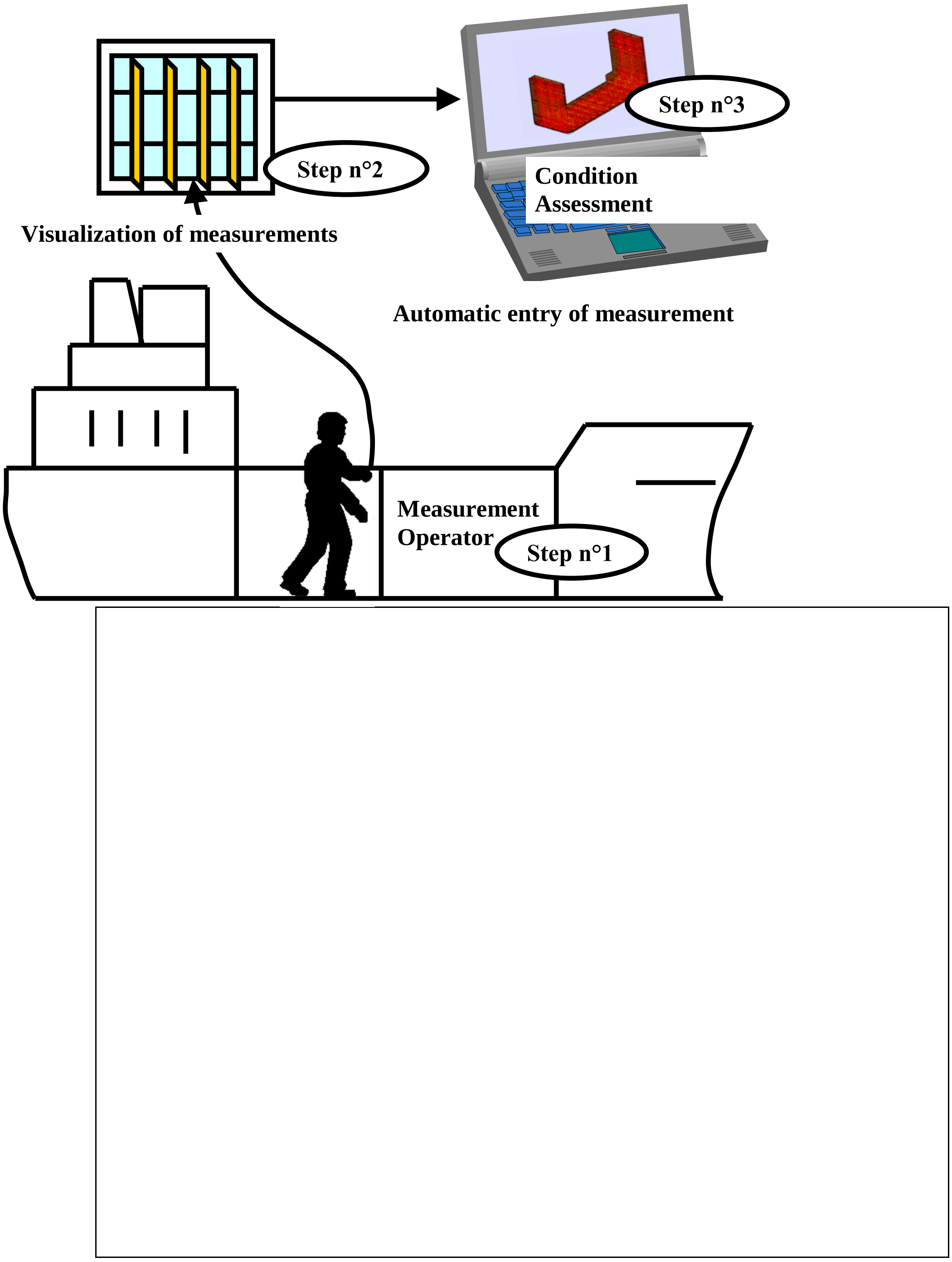

Figure 1 Re-engineering through CAS

1.2 Contractors involved

Bureau Veritas - Classification society - France (Project coordinator)
Germanischer Lloyds - Classification society - Germany
Materiaal Metingen Europe (MME) - Thickness Measurements company - Netherlands
SENER - Engineering company and Software editor - Spain
Instituto Superior Tecnico (IST) - University - Portugal
LISNAVE - Repair shipyard - Portugal
Cybernetix - Robot designer - France
Intertanko - Shipowners' association - Norway

TOTAL - Oil company and charterer - France
Russian Maritime Register of Shipping (RS) - Classification society - Russia

1.3 Work performed and end results

1.3.1 *Methodology*

It was decided that the re-engineering of the process was to include the definition of a standard exchange database, called Hull Condition Monitoring (HCM). The HCM was to be tuned up by all the partners intervening in the process, and, as studies and tests would be performed by the partners, in the course of the project, new features would be incorporated into the standard.

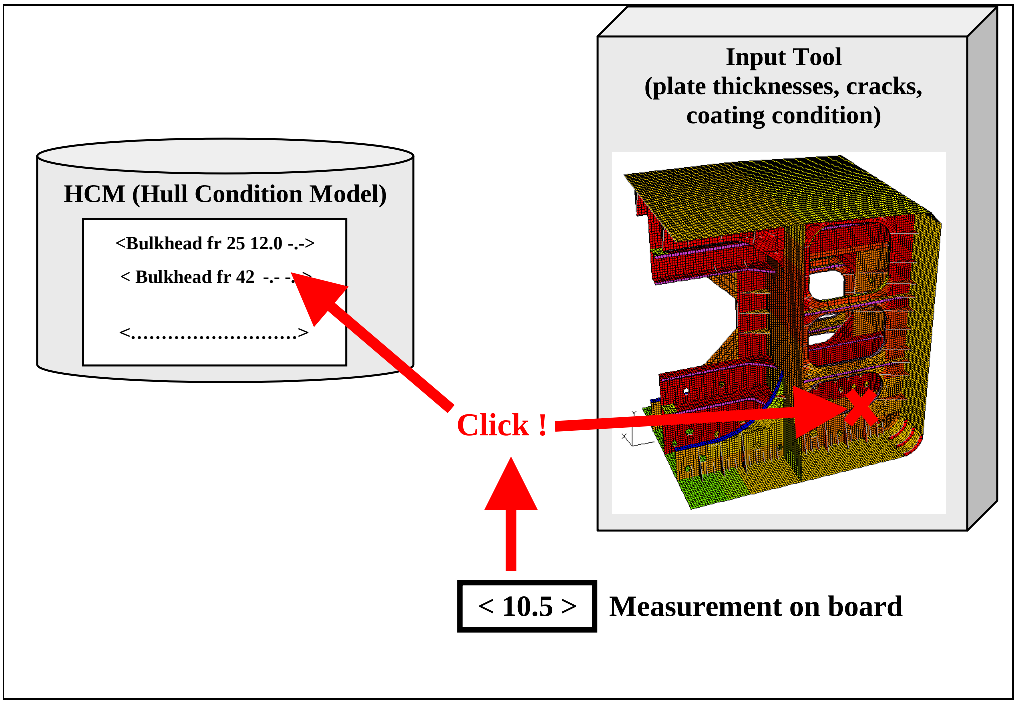

Figure 2 HCM correlation with 3D visualisation

1.3.2 *Ship measurements modelling*

1.3.2.1 Business Process Analysis and Optimization

The user requirements were listed, taking into account the variety of the partners' points of view, representing different roles in the condition assessment process.

The HCM design was especially focussed on:

- measurement data, corrosion, cracks and painting.
- geometrical information required for the definition of plates (planar, curved and corrugated) and profiles.
- the possibilities for the export out of a current CAD geometrical ship's model, used by the shipyards to build the ship, towards an HCM model.

1.3.2.2 Ship measurements modelling and visualization

Users' requirements were translated in the form of UML graphics (Unified Modelling Language). UML enables an easy graphical representation of the functionalities that will later be programmed.

The repair phase was included in the analysed HCM process, resulting into a re-design of the data model, which finally became Hull-condition-centric rather than Thickness-measurement-centric, as considered initially.

1.3.2.3 Hull Condition Model

For implementation in the software tools developed in the course of the project, version 0.62 of the schemas was selected. However, the model was further developed, so that for publication in the project website and to IACS Survey Panel, a more advanced version was selected, the version 0.70.

The major evolutions of the HCM data model during the course of the project were:

- change from Thickness-measurement-centric to be Hull-condition-centric.
- addition of inspection results beyond thickness measurements (coating condition, cracks, etc), repair data and corrugated bulkheads.

1.3.2.4 Interfaces between existing 3D model generators and HCM

The 3D model generators from two classification societies in the project, the 3D model generator developed in the course of the project and a shipyard CAD software could successfully produce HCM files.

Inversely, those HCM files, with measurements included, could be read by the 3D model generators from two classification societies in the project, as well as by the 3D model generator developed in the course of the project.

1.3.2.5 Geometric input tool

A prototype 3D model generator was implemented to produce, in a short period of time, a ship 3D model in accordance with the HCM standard.

From the geometric point of view, the model does not need to have high accuracy, because a simplified geometric description, based on linear approximations of both curves and surfaces, was adopted in the HCM. However, all the plates and stiffeners to be inspected during a campaign must be present and identifiable on the model.
So, it was assumed that the simplified model should be feasible from the information on the drawings commonly existing on board the ship, such as the general arrangement, body plan, midship section, etc.

In case neither the body plan nor an offset table is available, a rough hull shape must be defined using the existing data, which was also implemented in the prototype.

For each of the structural systems (bulkheads, decks, etc), generating templates were defined. Each generating template defines a family of structural system members, with similar shape and scantlings.

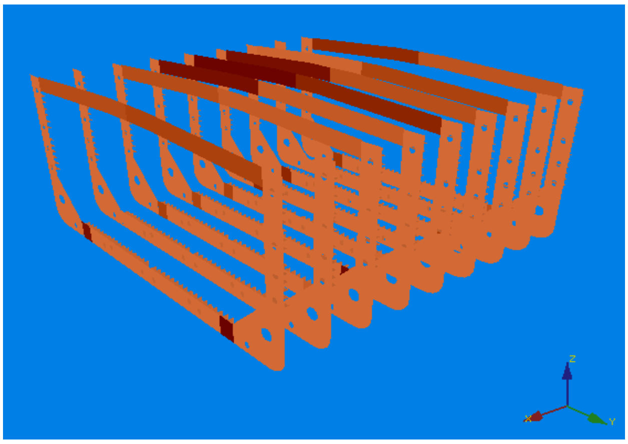
Fig. 1: Web frames

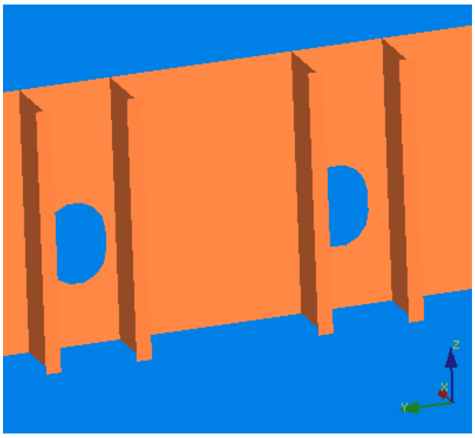
Fig. 2 Simplified plate and stiffeners

1.3.2.6 Visualization and Virtual Reality tools

The Visualization tool developed in the project could read the XML files in the HCM format and visualize the structural elements in 3D.

The Virtual Reality tool included a functionality to export the 3D model to a "Ray tracing" format, to generate photorealistic images.

1.3.3 *Appropriate measurement technology*

A strength and weakness analysis of all possible methods and available technologies for Thickness Measurements and cracks detection was carried-out.

A procedure for the application of Eddy Current crack detection was provided.

The standards for the inspection of corrosion prevention measures were analyzed, including the inspection of coatings as well as the inspection of cathodic protection systems.

Leading edge coating assessment technologies were tested.

1.3.4 *Assessment of ship condition*

The condition assessment tool developed in the project included the display, with colour codes, of the current and predicted steel wastage. Calculation of the equivalent age of the vessel, based on statistical methods, was implemented.
Calculation of inertia modulus for any ship's section and the consequences of the entry into force of the Common Structural Rules for oil tankers and bulk carriers, was documented.

1.3.5 *Risk-based maintenance planning*

The Risk Based Inspection (RBI) methodology adapted to HCM was developed and applied to the final demonstration.

The procedure comprised a segmentation of the ship structure in areas of similar degree of risk, an estimation of the risk and an adjustment of inspection planning.

1.3.6 *Demonstration in repair shipyard*

1.3.6.1 Scope of the demonstration

A demonstration of the CAS process in realistic conditions was performed in an European repair shipyard, on board a 150 000 DWT oil tanker, in dry dock. The ship's renewal survey measurement campaign was carried out using the CAS process and prototype tools, as developed in the project.

The demonstration proved that it was possible to build a 3D model of the whole ship, where the areas to be measured are represented with greater detail than the rest of the structure. Measurements on board consisted of measurements taken inside the ship by two UTM operators and on the outer shell by a robot.
The combined measurements were entered into the HCM model and analysed using the post-processing tools developed in the project, i.e visualization and virtual reality, condition assessment and interfaces towards class 3D model generators.

A film was built from both the video taken in the shipyard and the software tools screen copies.

1.3.6.2 Measurements inside the ship

Measurements inside the ship were performed by a team of two operators:

- one operator is handling the ultrasonic probe and uses “Rope access” to move inside the ship's tanks
- another operator is handling the computer and is located in an equipped container on the deck of the ship.

Both operators communicate through sound headsets and a video camera, in order to define, on the HCM ship's 3D model as displayed on the screen of the computer, the location of the measurements being taken. The measurements values sent by the ultrasonic probe are automatically entered into this HCM model, each time the operator on deck touches the image of the structure on the screen of his computer.

In parallel to thickness measurements, coating quality measurements were conducted using a leading edge technology.

1.3.6.3 Robotics demonstrator

A non-contact ultrasonic three-probes sensor was selected. Water was continuously injected to play the role of a coupling between the probes and the steel surface to be measured.
The probes were mounted in a self-adhering plate equipped with magnets, and linked to the robot by a flexible sheet.

A critical point was the estimation of the position of the robot in the ship. The only efficient and reliable solution found during the project was the attachment of three wires to the robot (odometry) and the continuous calculation of the position of the robot by monitoring of the length of those wires.

The robot interface read the vessel HCM model generated by the 3D model generator, retrieved the positioning and measurement data in real time, displayed it in a graphical way in 3D, and updated the HCM file with this data.

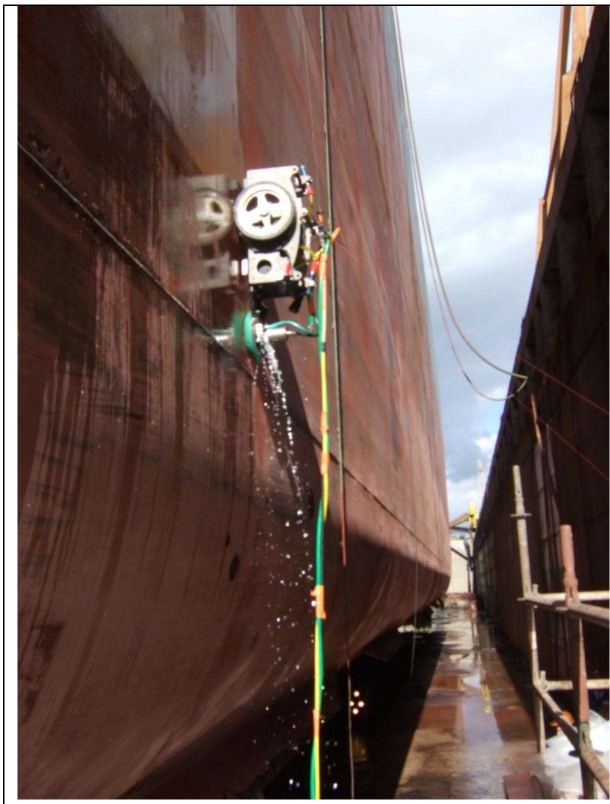

Figure 3 Robot on ship's hull

1.4 Degree to which objectives were reached

Globally the project has attained its objectives: The HCM standard was published and all prototype software tools used in the condition assessment process, from the initial thickness measurement to the final assessment of the ship's structure, were developed. The project has elaborated the core conceptual principles upon which all improvements of the condition assessment process of ships in service in the next years are expected to be based.

However, some prototype tools features, although still in accordance with the project principles, were not very easy to use: for instance, the entry of thickness measurements into the 3D model was done by typing in pop-up windows. In the final demonstration, more advanced features were supplied by some pieces of software developed by partners on the sides of the project, enabling for instance the use of a touch screen to enter more conveniently the measurements into the model.

1.5 Impact of the project

1.5.1 *Classification societies*

The major Classification societies were contacted in the form of the International Association of Classification Societies (IACS). The results of the CAS project, with respect to the HCM model, were presented at two regular IACS Survey Panel meetings in September 2006 and 2007 in Houston/USA.

Two classification societies involved as partners in the project have already developed their own commercial tools based on HCM. They are now considering the integration of those tools with other specialised modules in their own information systems.

1.5.2 *Maritime audiences*

Numerous conferences were addressed to maritime audiences, mostly in Europe, to make the maritime world conscious of the HCM potential.

1.5.3 *General public*

A project website was developed, for use by interested general public outside the project, containing seminar and conferences presentations, press releases, the standard HCM format itself to download as well as useful related links. The address of this project website is:
http://www.shiphullmonitoring.eu

2 Dissemination and use

- The result of the project is the Hull Condition Model (HCM) standard, which translates a ship's hull and the inspections carried out on this hull into a simplified 3D model. The 3D model is expressed as an XML file which can be visualized or enriched by specialised software, such as those developed in the project. HCM is a public and free standard.

  The main innovations consist in the fact that the resulting HCM 3D model is:
  - a standard, and is dedicated to all actors in the condition assessment process, and especially thickness measurement societies and classification societies.
  - a simplified model, good enough for ships-in-service maintenance, by opposition of the existing huge shipyards CAD models used for building the ships.

  Explanatory documentation on the HCM itself and the associated business process are available.

  HCM applies to ordinary ships of all types, but also to FPSOs (offshore oil floating storage) and jacket type offshore platforms.

  HCM is very much appropriate for connection with:
  - finite element models to calculate the stress levels in the hull structure
  - risk analysis modules to calculate the criticity of failures in the hull structure
  - condition assessment modules, visually showing the structural elements to be repaired
  - inspection/measurement robots

  We can expect those connections to be operational in about three years from now.

- The proof that the complete condition assessment process can be achieved using HCM as the only interface between the involved actors. This was illustrated by the final demonstration at shipyard.

- The feasibility of software tools development for:
  - a generator for simplified ship's hull models which can easily be exported to HCM
  - visualisation and virtual reality of the ship's hull and measurements using HCM
  - condition assessment using only HCM
  - automatically exporting the HCM simplified 3D ship's model, to be used during the whole operational life of the ship, from the shipyard CAD detailed 3D ship's model.

- The scantling prediction and statistics-based algorithms developed in the project for condition assessment purposes, which could be the foundation for future condition assessment tools, using HCM or not.

- The Risk based inspection methodology developed for the project, based on a segmentation of the structure, can be the base for the development of future Risk based inspection modules.

- The main features of a robot dedicated to thickness measurements on a ship's outer shell, including the sensors configuration and the positioning system. The robot itself is not patented, however the robot software, in charge of positioning the robot on the ship's hull is being recorded at the Programs Protection Agency.

