# Efficient Data Management for Hull Condition Assessment

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## Abstract

Performing inspections for Hull Condition Monitoring and Assessment as stipulated in IACS unified requirements and IMO's Condition Assessment Scheme (CAS) [5], [6] involves a huge amount of measurement data to be collected, processed, analysed and maintained. Information to be recorded consists of thickness measurements and visual assessment of coating and cracks. The amount of data and increasing requirements with respect to condition assessment demand efficient computer support.

Currently, due to the lack of standardization for this kind of data, the thickness measurements are recorded manually on ship drawings or tables. In this form, handling of the measurements is tedious and error-prone and assessment is difficult. Data reporting and analysis takes a long time, leading to some repairs being performed only at the next docking of the ship or making an additional docking necessary.

The recently started EU funded project CAS addresses this topic and develops – as a first step – a data model for Hull Condition Monitoring and Assessment (HCMA) based on XML-technology. The model includes simple geometry representation to facilitate a graphically supported data collection as well as an easy visualisation of the measurement results. In order to ensure compatibility with the current way of working, the content of the data model is strictly confined to the requirements of the measurement process. Appropriate data interfaces to classification software will enable rapid assessment by the classification societies, thus improving the process in terms of time and cost savings. In particular, decision-making can be done while the ship is still in the dock for maintenance.

**Key Words:** Hull Condition Monitoring, Condition Assessment Scheme, Enhanced Survey Programme, Engineering Data Modelling, Thickness Measurements, XML

## Introduction

When a ship is designed, the thickness of the hull plates is calculated in order to ensure the ship's integrity in all circumstances, but as time passes, the plates corrode and the thickness may be dangerously reduced. As the ship is being operated, its condition may deteriorate. In order to monitor their condition, ships are periodically checked by a Classification Society, according to specific rules which require close-up examination (visual control and touching of the plates) and thickness measurements (TM). In periodical measurement campaigns, typically performed by specialized TM companies, steel thickness is recorded in thousands of places in the ship's structure (about 20 000 measurement points for a large oil tanker). Cracks or coating condition may also be

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recorded at the same time. Measurement reports are checked by the class surveyor who would request repairs, in case of excessive wastage.

Processing of measurement and inspection information is currently performed manually, making it difficult and very time consuming to check the conformity to regulatory allowances. Classification societies systems cannot electronically read the measurement and inspection information issued by all TM companies, so that measurement reports can only be exchanged as pictures, text and tables. Furthermore, there is no electronic association between the measurements and the corresponding location in the ship's structure.

Only preliminary measurement reports are provided to the class surveyor for repair decision making. Later, when the final report is available, it might be difficult or costly to stop the ship for maintenance. Each measurement and inspection report is a sampling of the condition of the ship's structure (i.e. a few bulkheads and parts of decks and bottom) so that it is neither easily possible to assess the condition of the whole ship structure nor to assess the evolution with time of the ship's structural condition because measurements are not usually taken at the same place.

Integrated condition assessment systems are common practice in other industries, such as nuclear industries or oil refining. The difference is that there are a limited number of plants, located in fixed geographic areas, which facilitates the implementation of sets of sensing devices connected to complete electronic models and provides a lot of time for recording and analysing measurements. By contrast, each classification society follows several thousands of ships which navigate all around the world.

There have been developments in the past to organize recording of ship measurement information reports with some basic reference to the part of the ship measured (such as aft, forwards, portside, starboard), see e.g. [9], but it was not possible to ensure automatic electronic exchange from measurement information reports to computerised systems. For an overview regarding the current state and proposed developments regarding the inspection of marine structures see [2].

# Hull Condition Monitoring and Assessment (HCMA)

In general the monitoring of the condition of a vessel is one of the most important tasks of a ship owner to ensure long service life. This process influences directly the maintenance strategy and repair planning activities. From the owner's perspective the vessel must be operable as long as possible, while fulfilling all requirements of relevant regulatory bodies (IMO, Flag State Administration, Port State Authorities, classification societies) and of third parties (e.g. vetting companies, brokers). Certainly, for the owner, the objective of hull condition monitoring is to avoid any circumstances that could lead to unexpected stop of the operation of the vessel (unplanned repairs, port detention, class suspension, etc.) or even more severe incidents, like environmental pollution, in the worst case the total loss of the vessel e.g. due to collapse of the structure.

With respect to the maintenance strategy, the objective of the ship owner is to maximally exploit the period of time the vessel is in the dry-dock to perform all those inspections, surveys and repairs, which can only be carried out while the vessel is not in operation. In an optimal setting, any necessary repair work is carried out immediately after inspection during the same stay in dry-dock. For this reason the classification society and the owner must promptly have a clear picture about the condition of the steel structure (among other important aspects like machinery, steering gear, etc.).

For the purpose of properly deciding on the replacement of any structural elements due to corrosion degradation, the ship is continuously assessed by the Classification Society supervising the vessel. Classification Societies specify in their own regulations (construction rules and survey procedures) how, when and by whom thickness measurements should/might be carried out. The type, scope and frequency of thickness measurements depend principally on the vessel type and age. TM Companies are authorised by Classification Societies to carry out the measurements. Moreover, the International Association of Classification Societies (IACS) has elaborated Unified Requirements (UR) and standards for TM including scope, reporting of results and the procedures for the authorisation of TM companies, IACS URZ [4].

Today, typical TM campaigns require many thousands of measurement points, resulting in measurement reports of up to 500 pages or more. The data is acquired, written down and assessed point by point with only minimal computer support. TM reporting is based on tabular representation of the measurements which is organised by plate strakes or by frame positions (so called "belts"). In some cases a graphical representation of the measured area (shell expansion or cross section) is included.

The format of the tabular representation of TM has been defined by IACS in its Unified Requirements, IACS URZ [4]. However, as these are so-called "recommended procedures", each Classification Society has implemented own versions of the tables. An example is given in Fig. 1. TM recording procedures recommended by IACS are referred to in this paper as "the IACS tables".

| Ship's name | [redacted] | | | | | | | Class Identity No. | | | [redacted] | | | | | Report No. | | | [redacted] | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STRAKE POSITION | 8th strake from keelstrake, upper bilge strake | | | | | | | | | | | | | | | | | | | | | | |
| PLATE POSITION | No. or Letter | Org. Thk. mm | Maximum allowable Diminution mm | Forward Reading | | | | | | | | Aft Reading | | | | | | | | Mean Diminution % | | | |
| | | | | Gauged | | Diminution P | | | Diminution S | | | Gauged | | Diminution P | | | Diminution S | | | | | | |
| | | | | P | S | mm | % | | mm | % | | P | S | mm | % | | mm | % | | P | | S | |
| 7th | J15 | 17,5 | 2,03 | 17,5 | 17,6 | -- | -- | | -- | -- | | 17,5 | 17,5 | -- | -- | | -- | -- | | -- | | -- | |
| 6th | J14B | 17,5 | 2,03 | 17,7 | 17,8 | -- | -- | | -- | -- | | 17,7 | 18,1 | -- | -- | | -- | -- | | -- | | -- | |
| 5th | J14A | 35,5 | 3,00 | 35,4 | 35,6 | 0,1 | 0,3 | | -- | -- | | 35,3 | 35,6 | 0,2 | 0,6 | | -- | -- | | 0,4 | | -- | |
| 4th | J13 | 35,5 | 3,00 | 35,7 | 35,4 | -- | -- | | 0,1 | 0,3 | | 35,4 | 35,4 | 0,1 | 0,3 | | 0,1 | 0,3 | | 0,3 | | 0,3 | |
| 3rd | J12 | 35,5 | 3,00 | 35,3 | 35,2 | 0,2 | 0,6 | | 0,3 | 0,8 | | 35,4 | 35,2 | 0,1 | 0,3 | | 0,3 | 0,8 | | 0,4 | | 0,8 | |
| 2nd | J11 | 35,5 | 3,00 | 35,3 | 35,8 | 0,2 | 0,6 | | -- | -- | | 35,4 | 36,0 | 0,1 | 0,3 | | -- | -- | | 0,4 | | -- | |
| 1st forward | J10 | 25,5 | 2,75 | 26,0 | 25,8 | -- | -- | | -- | -- | | 25,4 | 25,7 | 0,1 | 0,4 | | -- | -- | | 0,4 | | -- | |
| Amidships | J9 | 25,5 | 2,75 | 25,7 | 25,5 | -- | -- | | -- | -- | | 25,7 | 25,9 | -- | -- | | -- | -- | | -- | | -- | |
| 1st aft | J8 | 25,5 | 2,75 | 25,5 | 26,0 | -- | -- | | -- | -- | | 25,7 | 25,8 | -- | -- | | -- | -- | | -- | | -- | |
| 2nd | J7 | 25,5 | 2,75 | 25,8 | 25,9 | -- | -- | | -- | -- | | 25,8 | 25,9 | -- | -- | | -- | -- | | -- | | -- | |
| 3rd | J6 | 25,5 | 2,75 | 25,4 | 25,5 | 0,1 | 0,4 | | -- | -- | | 25,5 | 25,6 | -- | -- | | -- | -- | | 0,4 | | -- | |
| 4th | J5 | 25,5 | 2,75 | 25,4 | 25,2 | 0,1 | 0,4 | | 0,3 | 1,2 | | 25,2 | 25,6 | 0,3 | 1,2 | | -- | -- | | 0,8 | | 1,2 | |
| 5th | J4 | 22,0 | 2,43 | 21,6 | 22,1 | 0,4 | 1,8 | | -- | -- | | 21,9 | 22,0 | 0,1 | 0,5 | | -- | -- | | 1,1 | | -- | |
| 6th | J3 | 22,0 | 2,43 | 21,7 | 21,7 | 0,3 | 1,4 | | 0,3 | 1,4 | | 22,0 | 22,6 | -- | -- | | -- | -- | | 1,4 | | 1,4 | |
| 7th | J2 | 11,5 | 1,50 | 11,7 | 11,5 | -- | -- | | -- | -- | | 11,5 | 11,6 | -- | -- | | -- | -- | | -- | | -- | |
| 8th | J1 | 11,5 | 1,50 | 11,7 | 11,2 | -- | -- | | 0,3 | 2,6 | | 11,4 | 11,6 | 0,1 | 0,9 | | -- | -- | | 0,9 | | 2,6 | |

**Fig. 1**: Tabular representation of thickness measurements following IACS standards

# Data integration and design objectives

It is the goal of the EU funded project "Condition Assessment of aging ships for real-time Structural maintenance decision" (CAS) to integrate all phases of the ship condition assessment process by achieving seamless electronic data exchange between the measurements on board the ship and the use of structural assessment tools. A gain in overall efficiency of ship repairs and consequently in ship safety is expected from the integration of the process. Partners in the CAS project are Materiaal Metingen (NL), Sener (ES), Instituto Superior Tecnico (PT), Russian Maritime Register (RU), Lisnave (PT), Total (FR), Intertanko (Int'l), Cybernetix (FR), Bureau Veritas (FR), and Germanischer Lloyd (DE).

In particular, in the project a data model is being developed to support the HCMA process. One of the major aspects of the data model is the support for thickness measurement procedures as required by international regulations like IMO MEPC.94(46) also known as "Condition Assessment Scheme" (CAS), see [5] and [6], and the "Enhanced Survey Programme" (ESP) as specified in IMO Resolution A.744(18) as amended.

The developed data model, named HCM (Hull Condition Model), enables the storage of thickness measurement data with or without an existing 3D-model of the ship. The measurement points are associated with an explicit location on the ship using relative or absolute positions and additional attributes to facilitate the assignment to the respective structural component.

HCM will enable a wide range of TM processing and analysis technologies, which are impossible or too complicated today, such as statistical predictions of steel corrosion in ships and risk based maintenance.

For this purpose HCM has been designed to be:

- Simple: It supports the current procedure of thickness measurements, i.e. the information in a measurement file (instance document) is similar to the content (not the format) of IACS tables combined with sketches as used today.
- Flexible: It is possible to use the data model even if no structural model (e.g. in classification software) is available beforehand.
- Descriptive: It enables easy visualization of the measurement results.
- Unambiguous: In case a structural model exists, matching of thickness measurements to elements in the structural model is supported.
- Independent: measurement files can be processed by different applications implemented by different parties.
- Compatible: Compatibility with current working procedures is ensured. In particular, generation of IACS tables for reporting TM is possible. Nevertheless, the structure of the data model is independent of the organisation of the data in the IACS tables.
- Self-contained: One file contains all data from one measurement campaign. The data model does not depend on external XML schemas.
- Compact: Measurement files are reasonably small (e.g. by avoiding long names for elements and attributes).
- Extensible: Software developers are empowered to extend the data model as required for specific purposes.
- Open: HCM (not the measurement data, but the data model) will be freely available to all parties interested in developing software supporting Hull Condition Monitoring and Assessment (e.g. Classification Societies, software vendors). No proprietary data of any party's software system is included in the data model.

# Simplified Geometry vs. Complex 3D Model

The basis for TM data collection is the knowledge about the structure of the ship. This knowledge is used for

a) specifying measurement locations before the measurement,

b) for locating plates and profiles during the measurement, and

c) for associating measured thicknesses (and other findings) with plates and profiles in the report and assessment after the measurement.

This structural information is today contained in the steel drawings. In the event of a measurement campaign, the company contracted to carry out the work obtains the steel drawings from the owner and prepares adequate versions of the drawings for the measurements. In case no steel drawings are available (this might be the case with old ships, which have changed the owner several times) sketches of the measured structural members are elaborated from scratch. This is typically done by the TM firm.

Today, the measured thicknesses together with sketches are sufficient information for the later steps in the assessment. Therefore, the fundamental question in the design of a data model for HCMA is: “how can this information be organised so that

- not more information than today needs to be entered,
- data acquired once, needs to be entered only once, and
- maximal computer support for the assessment phase (visualization and longitudinal strength) can be given?”

In TM sketches only the information which is relevant for identifying the plates and profiles in the real ship is required (welding seams defining the shape and position of individual plates, original thickness of the plates, type and position of profiles), see e.g. Fig. 2. In contrast to an analysis model of the ship, a data model for HCMA needs no topological information (connectivity of plates) and only low precision with respect to the exact location of plate boundaries is required. In particular, gaps or overlaps between adjacent plates in the model pose no problem as long as it is possible for the TM staff to identify the particular plate in the real ship. In this way only a simplified 3D model needs to be built up and stored. Its complexity must be tailored to the measurement process.

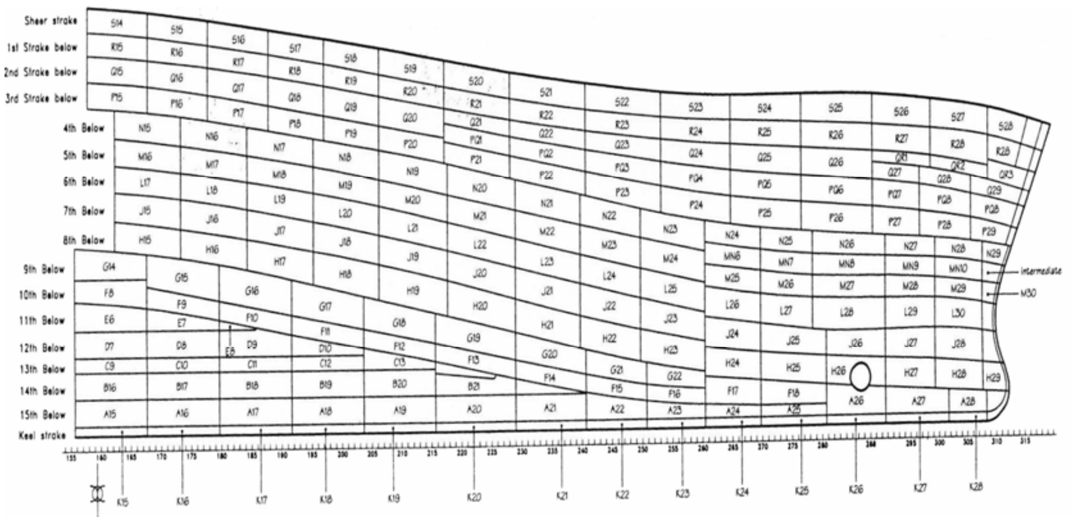


**Fig. 2**: Shell expansion sketch for TM purposes.

At present, the tabular representation of the data is typically prepared in the office after the measurement, while preparing the TM report. Depending on the size of the vessel and the scope of the measurements, this procedure may take up to several weeks. At this stage the matching between the sketch and the table is established. This is usually realised by numbering the measurements and using numbers/names or any other kind of denominations for plates and profiles.

When analysing the thickness measurements, the scantling requirements of the classification rules (corrosion diminutions) are checked for the individual plates and profiles. In the future, this task will be supported by a visualisation of the corroded state of the vessel.

For oil tankers and in some cases for other ship types (approx. 5% according to the experience of Germanischer Lloyd) the analysis is extended to longitudinal strength calculations using the measured hull condition, see Fig. 3. For this purpose, the current thickness of plates and profiles must be input into a calculation system (such as POSEIDON or VeriSTAR), which is usually based on a more complex 3D representation of the steel structure. Today the measurements have to be entered manually into such a program and an engineer might require up to several weeks to achieve this task. Too long, considering the relatively short time the vessel is in the dock.

Although current TM reports might be available electronically (e.g. as Excel sheets), there is no functional support for the analysis. An additional problem poses the fact, that different naming conventions for plates and profiles may be used in these tables for the same vessel depending on the company in charge of the measurements.

It is expected, that significant improvements can be achieved for the HCMA process using a simplified electronic model of the ship and the measurements as described above. In particular, faster assessment through visualisation and longitudinal strength calculation will become possible.

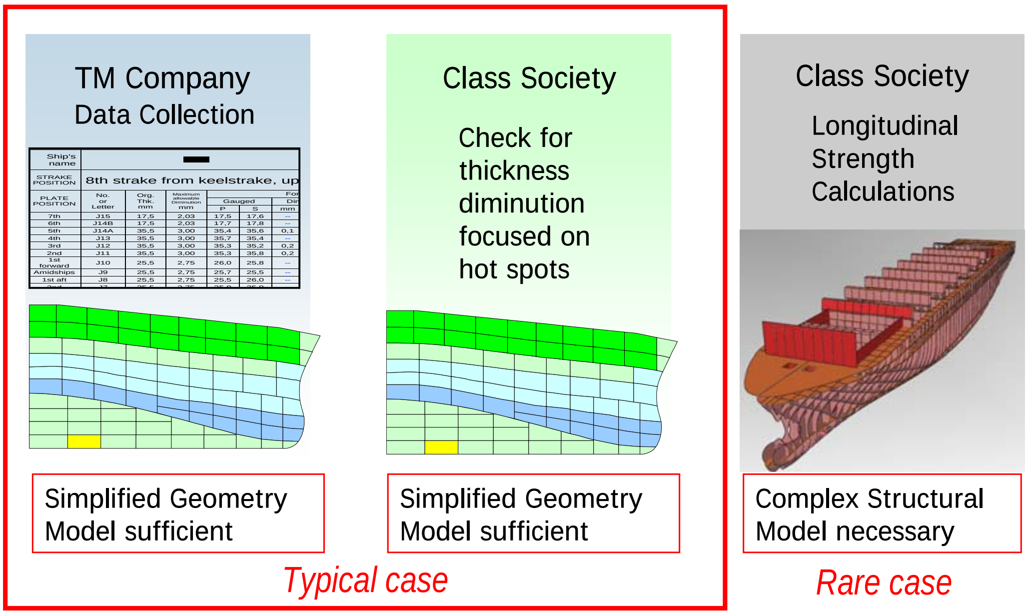


**Fig. 3**: Simplified Geometry vs. complex 3D model in the TM process

## The Hull Condition Model (HCM)

The data model HCM is currently being developed in the CAS project. In its current version it contains all information required for determining and analyzing the corrosion status of a vessel as required in current regulations. It includes data constructs for simple geometry information of plates and profiles. This simple geometry information enables the graphical representation of the structures for data collection, visualisation of the measurements and automatic association of the measurements to the corresponding plates and profiles in a more complex 3D model, e.g. for longitudinal strength calculations.

HCM also provides support for the use of incomplete models, i.e. models where only a part of the ship is defined, as well as for the incremental definition/population of the model data.

## The XML Approach

For the implementation of the data model the “Extensible Mark-up Language” (XML) has been chosen as the basic technology. More specifically an XML Schema approach is used to define the structure of HCM. As a modern and robust approach for structuring data, XML provides mechanisms for creating, storing and exchanging complex organised data by and between software applications and systems with or without human interaction. XML enables the combination of data contents and the meaning of the data through its "mark-up" approach. At the same time it supports the strict separation of data and its presentation, which plays an important role in the design and development of technical software.

Being derived from SGML (Standard Generalized Mark-up Language, ISO 8879) XML was initially designed and used for structuring electronic documents for the web. However, due to its extensibility and wide availability it rapidly became the favourite technology of software developers for defining industry specific data formats, so called "XML vocabularies". In fact, XML is not only connected to the XML specification 1.0 published by the World Wide Web consortium (W3C), Bray T. el al. [1], it is to be understood as a family of related and mutually complementing technologies, which extend the utilisation of XML to many business areas, including the storage, exchange and manipulation of complex technical data.

## HCM Modules

Using the *include* and *import* mechanisms of XML Schema, the data structures building up HCM have been arranged into the following components, each of which is implemented in an own XML Schema document. See Fig. 4.

Generic Product Data (hcm-pdt):

This module defines basic data constructs concerning general product data and geometry entities, which are not shipbuilding specific. It is not as complex as the constructs defined in ISO 10303-42, ISO1 [7], but from the point of view of design and implementation, it separates the more generic e.g. geometric part of the data model from the rest. For example, the "Polyline" data construct, which is a sequence of three-dimensional Cartesian points, is used in HCM to represent the contour of plates and the trace of profiles.

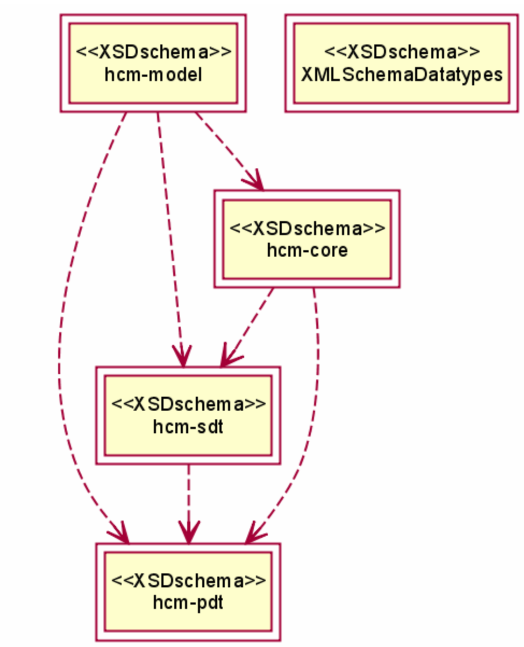


**Fig. 4**: HCM modules as UML package diagram

Generic Ship Data (hcm-sdt):

The shipbuilding specific data constructs are defined in this module. It contains general information about the ship and defines specific basic data types typically used in shipbuilding like frame spacing tables, principal dimensions, class data, statutory data, shipyard data, etc.

Hull Condition Data (hcm-core):

As its name implies, this module contains the core constructs to support the HCMA process. It represents all the data collected during a measurement campaign. It also provides mechanisms to establish relationships between measurements and their corresponding structural elements.

One of the key data constructs defined in this module is the one representing the measured vessel, which is called "MeasuredShip". Besides the generic ship data it contains the following information specific to HCMA:

Plates: each plate is identified by a set of attributes defining its position on the ship (strake, number, side, etc.) and may optionally contain information about its simplified geometry. The geometry of a plate is defined by its contour in 3D space represented by a closed 3D Polyline. As a consequence, the plate geometry can be as simple as possible (e.g. only 4 vertex points) or it may contain a more detail contour shape by including as many vertices as required.

Additionally, plate objects have an attribute "memberId", which points to one structural member (see below). This simple relationship between plates and structural members provides an easy mechanism to group, filter and select plates according to specific structural parts.

However, a plate does not include any topological relationship to other plates or other structural members. Each plate exists individually, without "knowledge" about neighbour plates. Thus, small deviations from their exact shape may occur (overlapping or gaps). The size of these deviations depends on the generating software.

Profiles: Profiles can be of two types: bar profiles (L-bar, HP profile, etc.) or built profiles (e.g. a T-beam consisting of a web and a flange). For both types, the simplified geometry is given by the trace line (represented as open 3D Polyline) in combination with the shape of the profile and the side information (which side of a plate, with respect to the global ship coordinate system, the profile is welded on).

Structural members: A set of extended structural components (in some software systems called "panels" or "functional elements") such as the outer shell, decks, longitudinal and transverse bulkheads, floor plates, stringers, etc. Each structural member has a unique identifier through which it can be referenced.

Compartments: Compartments in this context are spaces in which measurements concerning condition of the ship structure can be taken (cargo holds, tanks, etc.). Each compartment definition includes a list of plates and profiles which are visible (and hence "measurable") within the compartment. In HCM, compartment information is optional.

Gauging: A "Gauging" represents an individual measurement on a structural part (plate of profile) independently of the way is has been taken or the way it will be presented (e.g. in the IACS tables). It contains information about the measured value (e.g. plate thickness), the relative position of the measurement on the plate or profile, and a reference to the plate or profile object on which the measurement has been taken.

Gaugings can be grouped together into measurement groups, providing an additional mechanism to organise the measurements for the purpose of data collection or reporting. For instance: "all measurements taken within a cargo hold".

Extended Data (hcm-xtd):

This module (not displayed in Fig. 4) provides a framework for attaching information like digital pictures, sketches and annotations to plates or profiles.

Hull Condition Model (hcm-model)

This is the main schema representing the data model and assembling the data constructs defined in the other modules.

The central data construct (element) defined in this module is the "Measurement Campaign" (or just "Campaign"). The "Campaign" is the root element in an instance file and contains all other data constructs. All information and data collected during a measurement campaign should be contained in one HCM instance file.

# XML Schema Design

Following the "venetian blind" XML Schema design pattern, Costello R. [3] and McBeath D. et al [8], most HCM modules contain at the global schema document level only definitions of element types. In the whole data model only one global element definition is contained, avoiding ambiguity for the root element and supporting extensibility.

Figure 5 shows a graphical representation of HCM as simple Unified Modelling Language (UML) class diagram, showing the relationships between different data constructs.

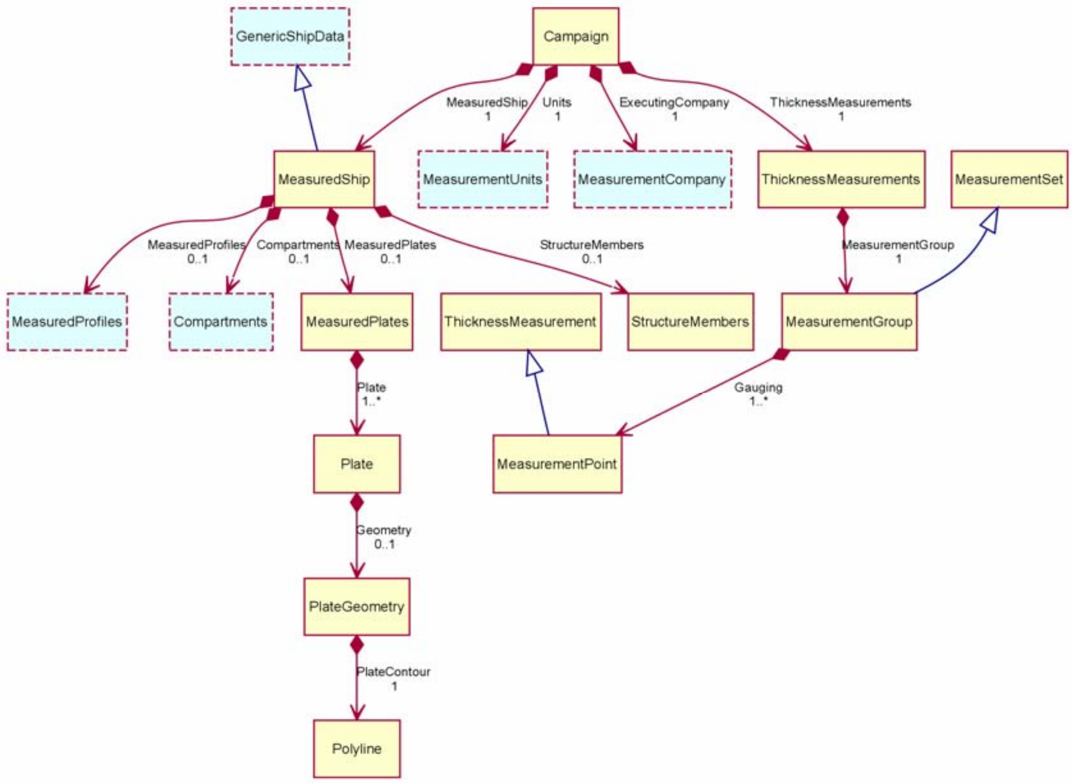


**Fig**. **5**: HCM Data Constructs as simple UML Class Diagram

# Deployment Considerations

Today's HCMA process is dominated by the handling of paper based information. Since the main design objective of HCM is to improve this process by electronic exchange and analysis of data, business process re-engineering (BPR) is performed in the CAS project to optimally exploit the benefits.

A major advantage of the HCM is that it can support the measurement process to different degrees. In a **minimal scenario**, only the Excel files are replaced in the current procedure:

- The Excel tables used by most classification societies today can be replaced by HCM files containing the same information. In this case, no geometry information about plates or profiles is entered into the system, but only plate and profile names and measurements are stored in the file. In this case, preparation of manual or e.g. AutoCAD sketches will be continued and only the transfer of the data will be improved by using a standardised format which is easy to process electronically.

In an **optimal scenario** the complete process will be handled electronically. The following procedure outlines an example of such a process:

- The ship (or the part of the ship which has to be examined, e.g. several cargo holds) is modelled by the classification society in their dimensioning software. Although this is a more complex model, there are advantages for building up this classification model when longitudinal strength assessment becomes necessary at a later stage.
- A simplified 3D model of the ship in HCM format is derived from the classification model.
- This model containing only simplified plate and profile geometry is given to the TM firm. The same HCM file can also be used to describe the required scope of measurements
- Thickness measurements are performed and added to the HCM file by the TM firm.
- In case measurements have to be made for plates or profiles with no geometry in the HCM file, this geometry can be added by the TM company. For this purpose a computer tool for fast and easy input of the location of plates and profiles is required.
- The completed HCM file is sent back and the thickness measurements are analysed and assessed by the classification society.
- The owner can access hull condition data and the measurement report of his ship.

As suggested above, in future the generation of the "simplified models" is likely to be a task for the classification societies. This approach will ensure a concise and consistent data management and the integration with analysis systems. In fact, the centralised hosting of TM data and other information concerning the condition of a ship has clear advantages for the ship owner. According to the concept developed within the CAS project, these documents will be in future HCM files or databases.

The development of software based on HCM plays an important role in the design concept. New functionality is needed at various stages. This can be contained in a single program but also specialised tools are conceivable:

- Output interface for classification software such as POSEIDON or VeriSTAR. Using this interface, the geometrical information for plates and profiles is generated from classification software.
- A measurement input tool is used for TM data collection and storage in HCM format.
- Sketch input tool. This is particularly important when an extended scope of measurements becomes necessary during the campaign and new geometric information about more plates and profiles needs to be entered.
- A visualization and assessment tool to support fast analysis of corrosion degradation.
- A module for the generation of IACS tables according to the recommended procedures.
- An input interface for reading in measurement results from the HCM file into classification programs.

Defined as open, neutral data format, HCM is intended to be supported by software systems of the different classification societies or other companies providing software to the maritime industry. In particular, the definition of the ship structure in CAD programs such as NAPA Steel, FORAN, TRIBON, and NUPAS can be used to generate the simplified geometrical information needed for the hull condition monitoring process.

The XML approach chosen in the CAS project provides a wide range of possibilities in the area of software development, enabling also the future integration and adoption of emerging inspection technologies and innovative measurement devices like robotics and remotely operated underwater vehicles (ROV).

Software implementations for the aforementioned cases (model generation, data collection, visualisation and analysis) are within the scope of the CAS project.

## Conclusions and Outlook

HCM, a data model for the storage and exchange of hull condition data acquired during ship inspections, has been introduced. This model is the basis for the electronic integration of the hull condition monitoring and assessment process of ships. Regarding the huge amount of thickness measurement data that is acquired today during a typical survey, it becomes clear that in this way tremendous gains in efficiency and assessment quality can be achieved. Manual browsing of tables will be replaced by up-to-date visualization and prompt verification of the structural strength of the ship in its corroded state.

The HCM data model will be made publicly available in order to increase the support of the technology by software providers in the maritime industry. Due to the use of XML, the data structures are easy to interpret and development of new software interfaces becomes much easier. HCM will be proposed as a standard to the International Association of Classification Societies (IACS) in order to promote its use by the main actors in the thickness measurement process, in particular thickness measurements firms, ship owners, and classification societies.

Today's hull condition monitoring process is characterised by the exchange of Excel tables or paper documents. With the use of HCM and supporting software, it will become possible to electronically handle hull condition data acquisition as well as its preparation, analysis and assessment. Furthermore, when databases of earlier measurements for a ship are available over time, this data can be used for the prediction of the future corroded state and thereby provides an important element of risk based inspection and maintenance. By improving the hull condition monitoring and assessment process, HCM and supporting software will contribute to safer shipping and a cleaner environment.

## Acknowledgement

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