

Computer Support for Hull Condition Monitoring with PEGASUS

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Abstract

Corrosion is one of the major issues for the structural condition of a vessel during its service life. In case of tankers and bulk carriers this aspect is even more crucial due to the exposure of the structure not only to salt water, but also to other abrasive substances in the cargo spaces. In order to monitor the condition of structural components, condition assessments are conducted within the scope of class surveys, statutory surveys and ship owner's surveys in regular time intervals. Information to be recorded consists of thickness measurements and other findings affecting structural strength like cracks, coating and anode condition. Today, thickness measurements are typically recorded manually on ship drawings or tables, i.e. the recording and handling of such information is dominated by paper work, manual copying of data, and spreadsheets. The amount of data and increasing requirements with respect to condition assessment demand efficient computer support.

Currently, there is no standard for the storage of thickness measurement data. In this paper the development of a new computer tool is presented, which supports the thickness measurement process from planning through recording to visualization. The PEGASUS system makes use of a neutral data format for hull condition monitoring data, which has been developed for this purpose in the EU funded research project CAS. The foremost purpose of this data format is the easy association of survey findings with their location on the ship.

1 Introduction

The condition of the steel structure of ships is subject to requirements of classification societies as stipulated in the *rules for classification* on the one hand and to international requirements being controlled by statutory regulations specified in several IMO resolutions (e.g. A744(18) and MEPC.94(46)) on the other hand. Also from the business and operational perspective, the condition of the structure of any marine vessel (ship or any other floating unit) is a major concern for the owning/managing company during the whole service life. Since dry-docking stays represent an interruption of the service of the vessel, they must be kept to a minimum. Furthermore, for ship types most vulnerable with respect to corrosion (i.e. tankers and bulk carriers), special requirements from the cargo owner, vetting procedures and additional inspections such as CAP (Condition Assessment Programme), are common practice.

Usually, structural defects on ships are identified by means of visual inspections (marine surveys) and measurements using special instruments (e.g. crack detection, tightness, plate thickness, etc.). These inspections are carried out by surveyors of the classification societies, by specialized firms and sometimes by crew staff. Structural defects have often been classified into the following categories, e.g. in Weydling et al. (2003):

- Material deformation (buckling)
- Material Rupture (cracks, breach)
- Material Degradation (Corrosion, Abrasion)

While the first two categories are relatively easy to localize (except for cracks), quantify, and characterize, in the third case, especially when considering all possible types of corrosion (general corrosion, pitting corrosion, grooving corrosion, etc.), the characteristics of the defect are more difficult to describe, collect and report.

Corrosion is one of the most common types of deterioration of metal structures. It cannot be fully avoided in maritime business, since most marine vessels are made of steel being more or less exposed to water or aggressive substances during its service life. The focus of this paper is on *monitoring of*

corrosion as an important mechanism to have some control over the process and to prevent for instance structural failure or collapse, resulting in major damages for life and the environment.

2 Thickness Measurements (TM) for Corrosion Monitoring

Corrosion monitoring in maritime business is today typically performed through ultrasonic thickness measurements (UTM) carried out by qualified operators using specialized measurement equipment. Procedures for UTM are well established and mostly governed by requirements of the individual Classification Societies. The International Association of Classification Societies (IACS) has introduced so called *Unified Requirements* (UR) and *Procedural Requirements* (PR), covering explicitly the execution of UTM as part of the classification survey procedure, IACS (2004) and IACS (2006). The individual requirements are available for common ship types and include details on the scope and locations of measurements as well as recommendations for the reporting format (so called IACS TM tables, see Figure 1).

Ship's name	■■■■			Class Identity No.	■■■■			Report No.	■■■■										
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		

Figure 1: Tabular representation of thickness measurements following IACS standards

2.1 Need for process improvement

With respect to data collection and reporting, the current TM procedure is a highly manual process. The analysis and assessment of often many thousand measurement points result in up to 500-page report documents. Compilation of such reports is a tedious and long lasting process, which in most cases takes longer than the docking itself. Significantly shorter reporting times can therefore have a large positive impact on the monitoring and repair process as soon as it becomes possible that the report is ready before the ship leaves the dock.

Another important disadvantage of the current procedure is the lack of an automatic integration of measurement results with existing structural models of the ship, for the purpose of conducting e.g. strength calculations. Nowadays, any required TM data exchange is performed manually and redundantly, point by point. The major disadvantages of the current procedure can be summarized as:

- Data is entered redundantly (data collection → reporting → analysis)
- No link between tabular and graphical representation
- In many cases no graphical representation is available, in particular no adequate visualisation (colouring, 3D view, filtering, sorting, etc.)
- No data interface between the gauging device and the used software (e.g. EXCEL)
- No automatic transfer of the TM results to a class calculation systems

Considering the above mentioned aspects, the logical step for achieving an improvement in processing time and data quality is the provision of adequate IT support in terms of tools for efficient data input, assessment, and exchange and correspondingly tailored electronic data formats. For the last years this has been the subject of Research and Development activities at Germanischer Lloyd in close cooperation with industrial and academic partners. An example of such activities is the EU Research Project CAS, in which Germanischer Lloyd in cooperation with two other IACS society members (Bureau Veritas and Russian Register of Shipping) and other partners is developing a neutral Data Model for collecting, transporting and storing TM data as described in the following section. Building on this Data Model, Germanischer Lloyd has implemented the software tool PEGASUS, for TM data collection, visualisation and reporting. This tool is introduced in later sections.

2.2 Hull Condition Model (HCM)

In the current TM process, data collection is performed by noting the TM readings in previously prepared sketches and drawings of the measured parts of the ship. Commonly, AutoCAD or similar software is used for the preparation of such sketches. The TM campaign itself is often executed by two operators; one for placing the probe on the measured steel parts (e.g. inside a tank or climbing a bulkhead) and another for writing the results on paper. After the campaign, the final report is prepared according to IACS TM tables (see Figure 1). For this purpose, usually spreadsheet software (e.g. EXCEL) is used.

Typically, the CAD Drawings and the Excel tables represent today's maximum degree of IT support for the TM procedure. There is no standard electronic format for the TM data itself. Results of a process analysis, Jaramillo et al (2006), show clearly, that a standardized format to be used by all participants in the process in combination with adequate software tools would solve many of the aforementioned problems.

Consequently, the Hull Condition Model (HCM) data format developed in the CAS project aims specifically at improving the current TM process, Jaramillo et al. (2005). Furthermore, HCM covers other aspects of the Hull¹ Condition Monitoring and Assessment (HCMA) process beyond the scope of the Thickness Measurements, such as pitting corrosion, coating condition, buckling and cracks. HCM is based on XML technology and contains the data constructs which are necessary to transport information about the structural condition of a ship. The Data Model will be proposed to IACS for standardisation with the aim to reach wide acceptance and hence easy data exchange between the parties involved in the TM process.

HCM is a data model focussing on the service phase of the vessel. The foremost purpose of HCM is the easy association of survey findings with their location on the ship. Serving mainly this goal, the complexity and detail of the model is kept to a minimum.

For that reason, HCM uses *simplified geometry* in contrast to complex, topology-based structural definitions used for other purposes in shipbuilding, mainly during the design phase (strength calculation, manufacturing preparation, etc.). In HCM, simplified geometry is used

- for the graphical representation of the structural parts for both data collection and visualisation purposes and
- for mapping measurement results to a more complex analysis model.

The level of accuracy of the geometry representation in HCM is comparable to the one found in sketches and drawings prepared for the same purpose in the current process. The focus of the model is on the *identifiable shape* of each individual structural part and its position in the vessel. In contrast,

¹ The term "Hull" is used here to refer to all structural aspects of a vessel in contrast e.g. to machinery or parts of the electrical installation.

the relationships between the parts and their accurate shape are less important in this case. In particular, gaps or overlaps between adjacent plates in the model pose no problem as long as it is possible for the user to identify the displayed part and associate it with what is seen on the steel drawings or in the real ship.

The association between measured value and the corresponding structural part can be established by the user either by means of the position of the measurement point (transported in the HCM file) or by other linking mechanisms such as a naming scheme (i.e. a globally unique identifier) for each structural part. As soon as a measurement point has been entered, within the data model it uniquely references a plate and its local position on the plate.

3 TM Process with PEGASUS

PEGASUS is a software tool developed at Germanischer Lloyd to support the TM process. The tool is intended to be used by TM firm inspectors, by GL surveyors on site and by GL Hull Condition experts at the Head Office in Hamburg. When designing PEGASUS, special attention has been given to achieve fast and easy input and visualisation of TM data. Figure 2 shows a screenshot of PEGASUS in action.

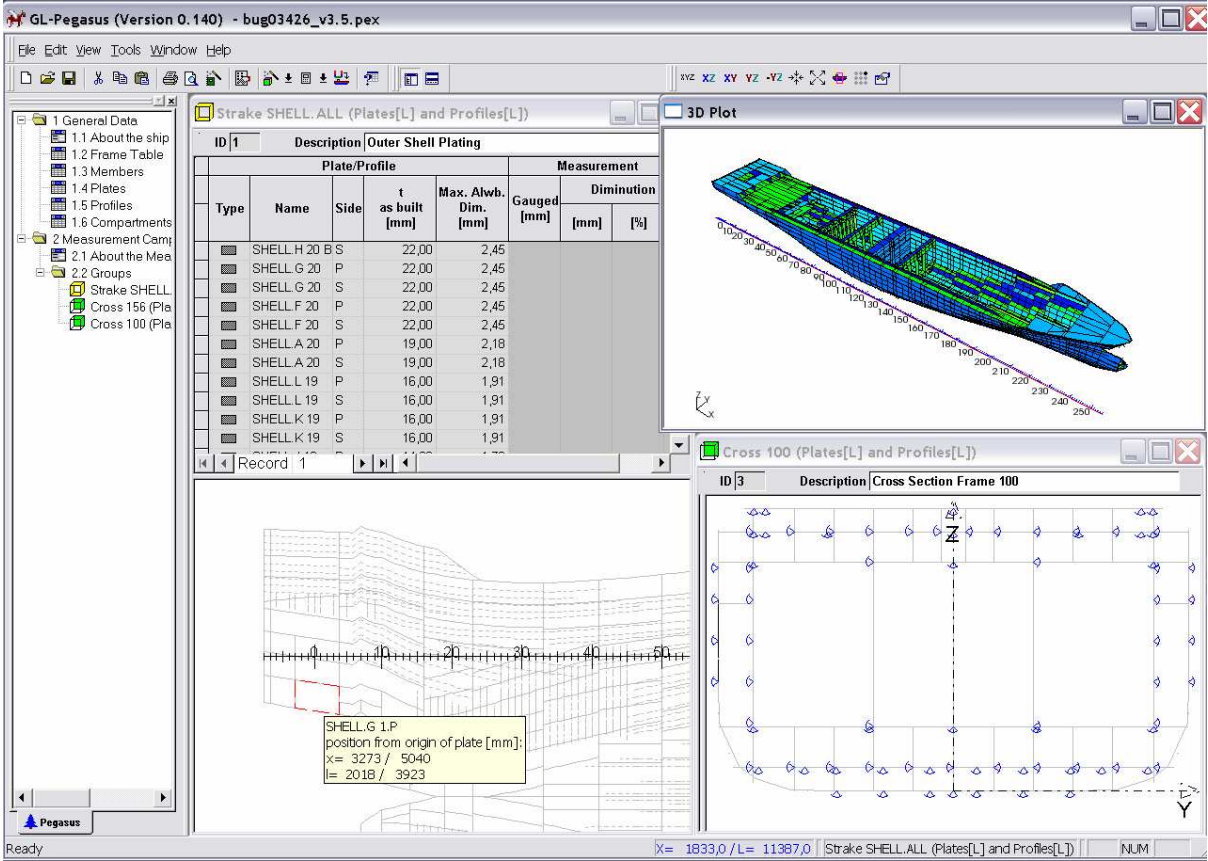


Figure 2: Screenshot of the PEGASUS application

The concept of the new TM process using PEGASUS is shown in Figure 3. Starting from an available POSEIDON structure model, the initial HCM file, containing the simplified geometry representation of the structure parts, will be generated by means of a corresponding data interface. At this stage, the HCM file contains general information about the ship, the frame table, information about each structural part to be measured (plates and stiffeners), the compartment definitions and a list of structure members. This initial HCM file (pre-survey status) is prepared at Germanischer Lloyd and sent to the corresponding TM firm.

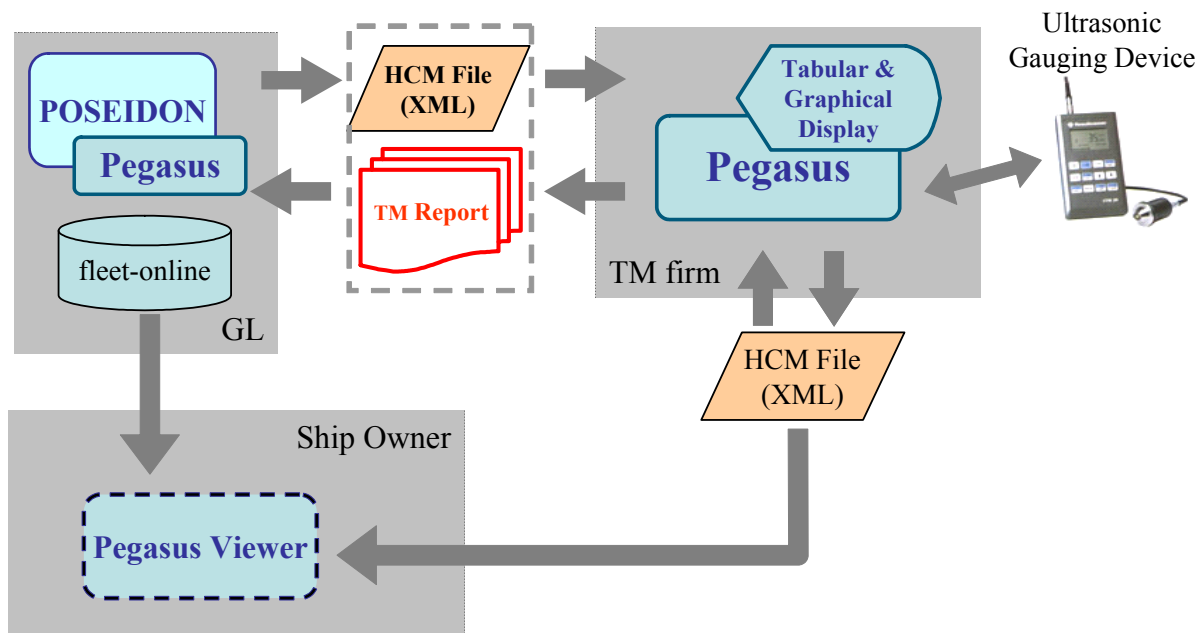


Figure 3: Sketch of the new TM process using PEGASUS

3.1 Preparation of the TM Campaign

At the TM firm, after loading the HCM file in PEGASUS the different "tasks" of the TM campaign can be prepared (so called TM Configurations). For this purpose it is possible to define:

- cross-section-based views of the structure, which are usual for so called "TM belts" at specific frame positions,
- strake-based views, which are usual for global thickness measurements on bottom, shell and upper deck plating,
- compartment-based views, which correspond to the natural measurement procedure in closed spaces or
- user defined configurations of the structure parts to be measured.

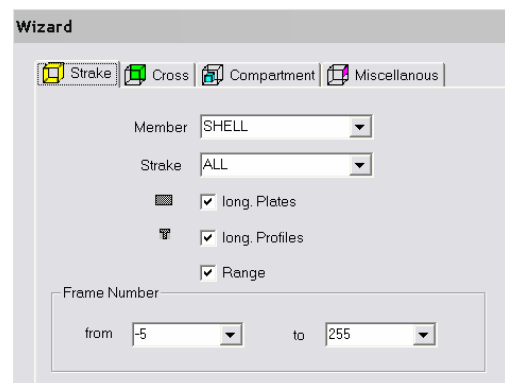


Figure 4 Creating TM configurations

The corresponding dialogue is shown in Figure 4.

A TM configuration consists of a set of measurable structure parts, which are arranged according to a specific measurement task. For instance, if the task is to measure the whole outer shell plating, the common arrangement for data collection and reporting is strake based (based on the shell expansion drawing), but if the task consists of the measurement of a "belt", then a cross section based arrangement of the structure parts at the specific frame position is more convenient.

The PEGASUS screenshot in Figure 2 shows typical strake based and cross section based TM configurations. Data Collection can be achieved in both the tabular and the graphical view. Furthermore, the gauging values are visible independently of the configuration; e.g. readings taken in cross section view are visible in the corresponding position in the strake view and vice-versa.

3.2 Data Collection

PEGASUS has been designed to provide support in different user scenarios depending on aspects like

the different way of working of TM firms (e.g. number of operators) and the available equipment (simple or sophisticated gauging devices, data loggers, etc). Data collection is achieved by entering the measured values directly in the tables or in the graphical representation. Both views are interconnected and can be hidden or shown as required. The data can be entered in PEGASUS directly on site or later in the office. In the latter case, graphical views of the measured areas can be printed out and taken onboard for data collection. This approach corresponds to the current way of working, with the advantage, that once the data is entered in PEGASUS further processing is much easier than today with respect to reporting, visualisation, and assessment.

Additionally, a direct connection to an UTM device is supported. Depending on the used device, it is possible to have a one or two directional data exchange. In the first case the measured values are transmitted to PEGASUS and assigned to the corresponding position. In the second case a complete *measurement plan* can be sent to the UTM device. The inspector goes onboard with the programmed UTM device, in which the measurement plan can be displayed in tabular form, takes the measurements and sends all the results back to PEGASUS. Figure 5 shows a TM configuration in PEGASUS and the corresponding view on the display of a Krautkraemer DMS-2 UTM device.

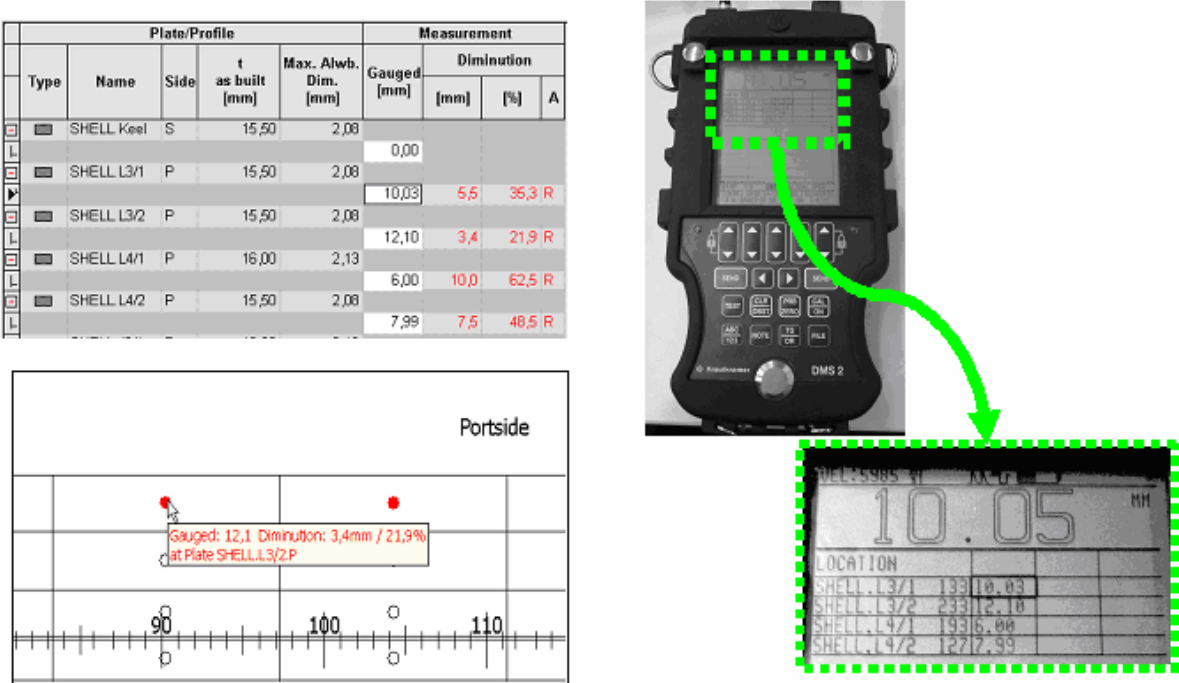


Figure 5: Data exchange with the DMS-2 UTM Device

3.3 TM reporting

After the data collection phase, the HCM file containing the measurement values is available (post survey status). At this stage the TM reports can be generated in PEGASUS according to the IACS requirements. To facilitate integration with word processing software, the Rich Text Format (RTF) has been chosen for this purpose (see Figure 6). In fact, automatic generation of IACS compliant TM reports represents one of the major improvements in terms of time saving with respect to the old process. PEGASUS provides flexibility in the composition of the TM report by means of a reporting wizard. Individual reports for each configuration (e.g. for daily reports) or a global report containing all available TM results can be generated.

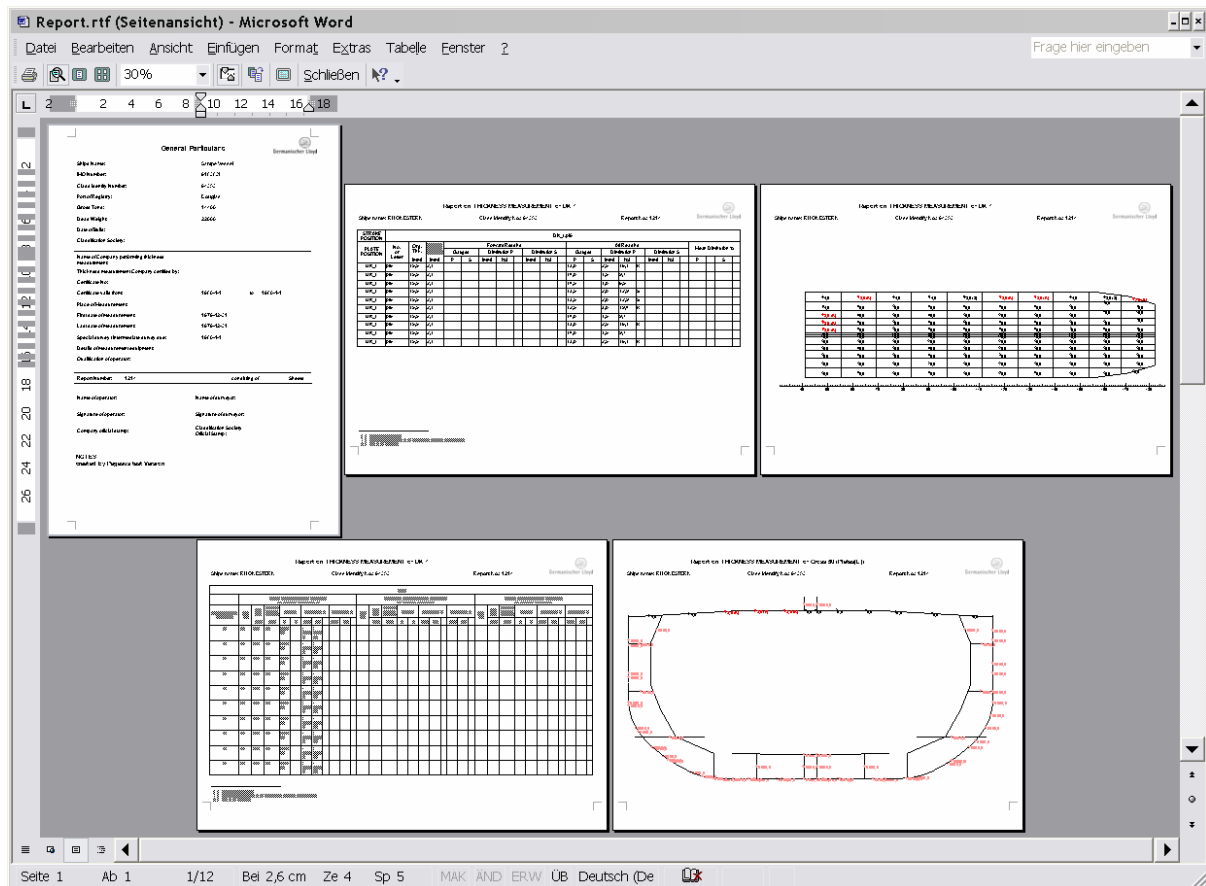


Figure 6: Automatically generated TM Report

3.4 Analysis and Assessment

Finally, both the TM report and the post survey HCM file are sent to Germanischer Lloyd (local and head office), where the analysis of the TM data is performed using PEGASUS. For this purpose, the visualisation mechanisms are used to easily identify the hot spots. If necessary, the measurement data can be imported into POSEIDON from the HCM file and longitudinal strength calculations can be performed using the measured thickness values.

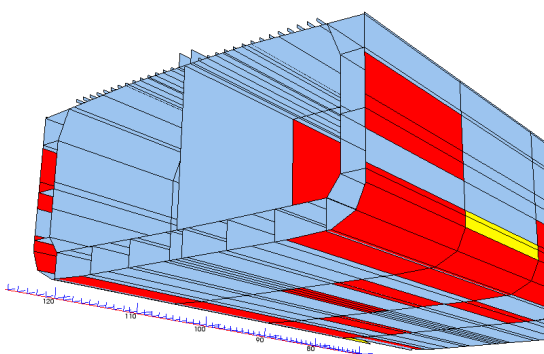


Figure 7 3D View in PEGASUS

As mentioned previously, an important aspect of the support provided by PEGASUS is the adequate visualisation of the TM data. For this purpose, a colouring scheme based on the degree of corrosion is used in both graphical and tabular views of the TM data. Additionally, the structural arrangements can be displayed in a 3D view providing a global overview of the measured areas. Figure 7 shows an example 3D view in PEGASUS colour coded with respect to thickness diminution.

For orientation purposes the frame scale can be displayed in both 2D and 3D graphical views. By placing the mouse cursor over a structure part, additional information can be shown like identification of the plate/stiffener or the name of

the structure member to which it belongs.

Measurement points are displayed in different ways. The displayed information can be configured, e.g. showing the id of the point, the measured value, or an assigned numbering for the UTM device configuration.

As the result of a TM campaign is contained in an HCM file, which is a neutral data format, the information about the corrosion status of the vessel can be provided to the ship owner via online services (e.g. GL's fleet-online). An HCM Viewer (e.g. a special version of PEGASUS) will be provided as a tool for the Ship Owner to adequately visualize the data.

3.5 Availability of structure models

In the last years, the creation of an electronic structure model has become part of the new-building process. In case of Germanischer Lloyd, the software used for this task is POSEIDON. For old ships such a structural model is rarely available today, but obviously a model that accompanies the vessel's life cycle is also beneficial in other cases than Corrosion Monitoring as e.g. for Emergency Response Service. For that reason, the number of ships in service for which structural models are available will clearly increase in the coming years. In the case of PEGASUS, an HCM file containing the part of the ship to be measured will be generated from a POSEIDON model. This POSEIDON model will most likely be prepared by Germanischer Lloyd.

4 Conclusions and Outlook

A new software tool supporting the thickness measurement process has been developed by Germanischer Lloyd. The target users of PEGASUS are TM firms and GL staff (Surveyors and Experts) for data collection and data assessment, respectively. Ship owners will be able to view results of thickness measurements in 2D and 3D visualizations with a special viewing program.

Instead of preparing sketches and drawings after taking the measurements, a structural model of the ship will be prepared before the inspection. A derived HCM model can then be used to plan the measurements. By directly associating gaugings to the model during inspection using PEGASUS, the complete results of the measurement campaign can be available directly afterwards. Thereby, inspection results can be presented earlier to the ship owner and potential sources of error are reduced because of significantly less manual interaction during measurement and reporting.

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