IMPROVEMENTS IN HULL INTEGRITY BY THE USE OF 3RD GENERATION MAINTENANCE MANAGEMENT SOFTWARE

D M Ribeiro, Federal University of Rio de Janeiro / PhDsoft, Brazil

SUMMARY

The use of hull life-cycle maintenance software since 1995 on 26 tankers has reduced inaccuracies in the evaluation of ship renewal costs during dry-docking. Due to its success the software has been redeveloped and extended for the whole floating fleet of a major Brazilian oil company, including 12 FPSOs and 5 Jack-ups. Some unexpected applications were also identified such as the replacement of regular drawings by the 3D models used in the software. While jack-ups' needs are very similar to ships since they can dry-dock, FPSOs have a totally different approach with attention to corrosion being the primary focus. The software allowed a sophisticated data acquisition process to be applied, capturing and applying large quantities of key information thus enabling risk-based inspection to take place.

1. INTRODUCTION

The first version of our hull integrity and maintenance software, Steelwork®, was developed in 1993 using MS QuickBASIC for DOS. This resulted from consultancy work undertaken to evaluate steel renewal requirements for a 270,000 ton ore-oil vessel to extend its life for 5 years.

By extrapolating old gauging data we gathered a comprehensive mapping of the hull and an estimate of the repairs required.

However we recognised that the amount of work required to extrapolate old gauging data with spreadsheets and to generate sketches to visually outline the repair regions, as we did in this case, would be impractical as a regular procedure. A new software package was necessary to address this issue.

In 1995 we developed the first Windows-based version which Petrobras then started using for maintenance of their tanker fleet. This first version worked in two dimensions only since at that time most users were used to 2D drawings. In 1997 it became the underlying technology for the ABS (American Bureau of Shipping) SafeNet® structure maintenance system.

Using our 12 years of experience with Steelwork® and addressing its obsolescent features, we developed the 3rd generation software PHDC4D®. This was released in 2006 after more than three years development.

This paper details our experience with the implementation of the technology and the implications for hull integrity.

2. BACKGROUND

When the first version of the software was developed many authors took the view that it would be very difficult to implement a system to manage hull integrity due to the complexity of the geometric interface. Maintenance software was based on tables and organised by part numbers that would not be available in structures.

Regular equipment degradation measurement was easier since one could always refer to a specific part of such equipment by its part number. The shaft for example might be part number 10011. A table like that shown in Figure 1 could then be used to follow it's degradation.

Part Number	Description	Type of Degradation	Degradation measurement	Date
10011	Shaft	Diameter reduction	0.010 mm	26/05/76
10011			0.015 mm	03/08/92
10011			…..	……

Figure 1: Example table for regular maintenance.

Using temporal information degradation could be extrapolated and a prediction made as to when the shaft should be repaired or replaced.

The same approach could not be applied to structures since degradation only occurs in certain areas.

Figure 2: Ship hull with degradation area.

How could the whole structure be sub-divided in such a way as to represent an area like that shown in Figure 2 ?

However we were able to prove that it would be possible to use a new approach by developing a DOS based application in 1994 as shown in Figures 3 and 4 where a Petrobras barge has been modelled [1].

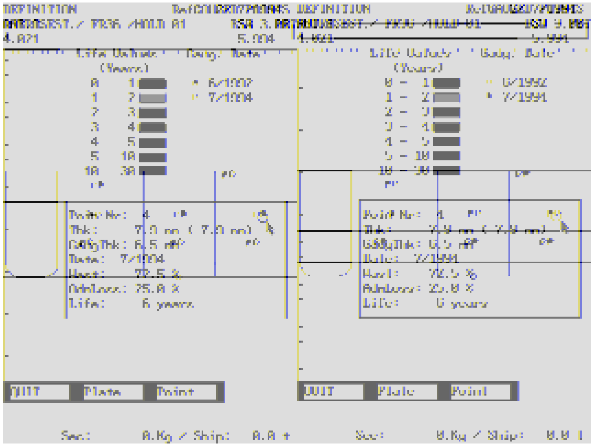

Figure 3: Steelwork® DOS version in 1994- gauging

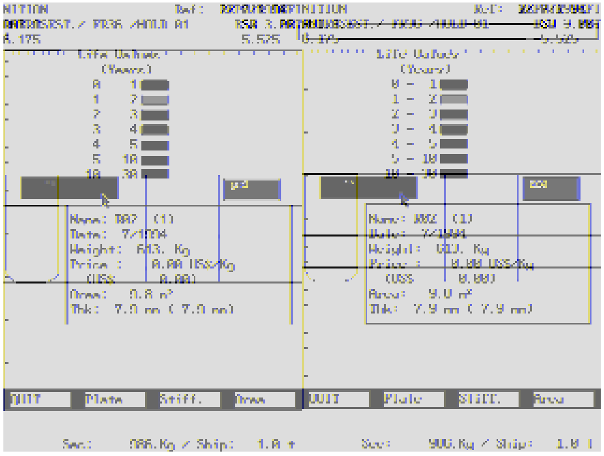

Figure 4: Steelwork® DOS version in 1994- repairs

At the same time Classification Societies were adopting the use of IACS' TM (Thickness Measurement) Reports. The structure was being considered as a set of plates and the maximum level of accuracy was the half plate. Those reports were very appropriate for the manual processes available in the 1990s.

TM Reports represented a transition stage to a more computer-based tracking procedure. Today they are still necessary since most TM companies still do not use a computer system to send information to Classification Societies, ship or rig owners and operators.

In 1995 we released the first Windows version [2], still two dimensional, as illustrated in Figure 5. For this version models were developed for 26 tankers, 12 FPSOs and 5 jack-ups.

The software was well received by users despite the lack of a 3D interface. It was able to keep track of thickness gauging and repairs, amongst other features. If the only goals of such a computer system were storing gauging and repairs then 2D would be sufficient since the additional work necessary to build a 3D model could not be not justified without additional functionality to exploit the extra dimension.

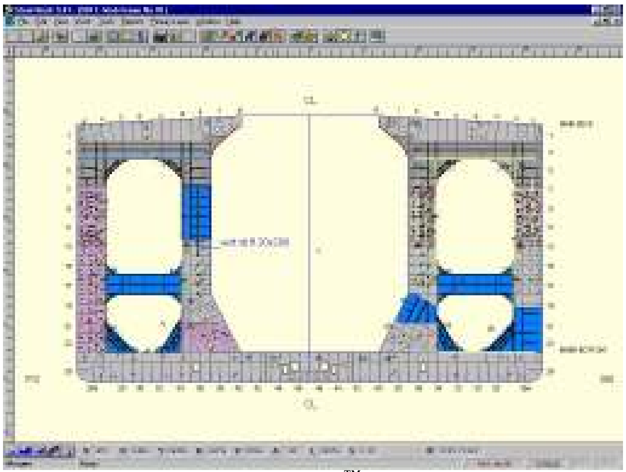

Figure 5: Steelwork® Windows™ version in 1995

In 2003 we started to developing a new 3D version using C#. It soon became apparent however that the 16 bit Visual Basic programming language and MS Access could not support the increased sophistication of the software. 32 bit Windows was also becoming the standard operating system and eventually it would not have supported 16 bit applications.

Considerable effort has been put into reprogramming and conversion of 2D models to 3D. What used to be a 700 man hours task to produce 2D ship models doubled. This is due to the increased accuracy required to connect sections in space and because many sections are not flat like deck and shell.

The first 3D model produced was of the Petrobras P40 semi-submersible rig shown in Figure 6.

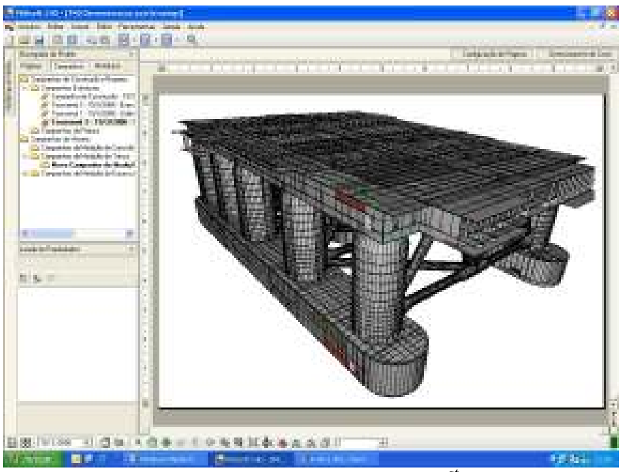

Figure 6: P40 modelled in PHDC4D® - 1st 3D model.

This represented a proof of concept since it was the largest Petrobras rig and if the software worked well with this model then we could assume it would work well with any other. We would see later that Shell's FPSO

Fluminense model was even more demanding due to the hull shape (see Figure 7).

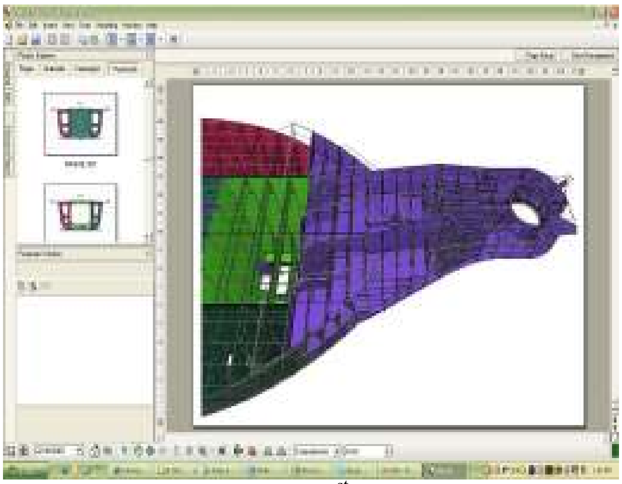

Figure 7: FPSO Fluminense - 1st 3D FPSO.

3. CORROSION RATES

3.1 GAUGING QUALITY

Gauging quality is the main issue for determining corrosion rates. In our experience much of the gauging work is incorrect. We have been collecting gauging data for 13 years and around half of the values seen are larger than the original thicknesses (see Figure 8).

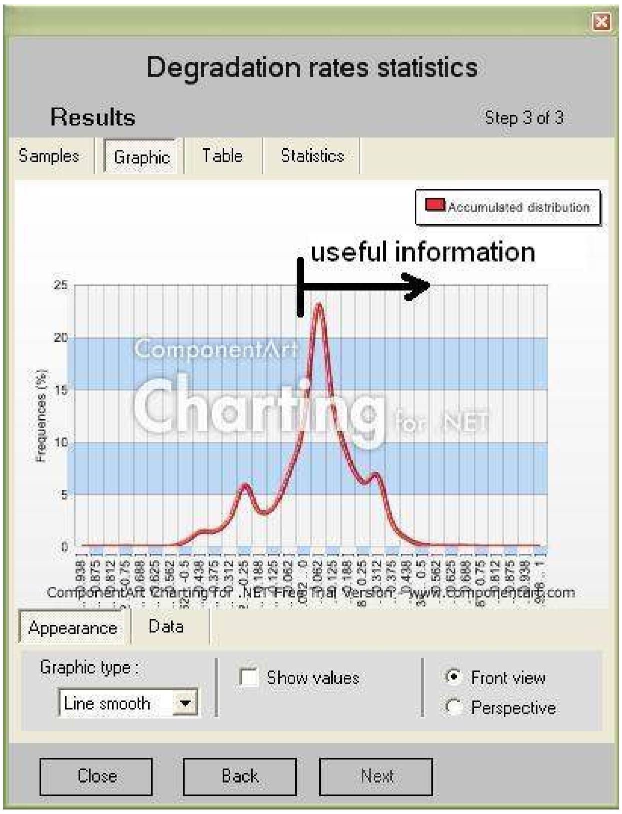

Figure 8: Corrosion rate distribution of a FPSO.

We recently undertook an FPSO gauging campaign which resulted in more accurate data being acquired. Much of the previously acquired data had been less than or equal to the original thickness. The improved quality control provided by the new software for data acquisition helps to ensure that TM companies deliver more consistent results.

The next step would be to allow TM companies to feed data into the system directly while undertaking the gauging work on board. A potential problem with this approach however may be that the instant feedback of erroneous measurements could stimulate two different behaviours: artificially fix the values or repeat the gauging. Procedures would need to be carefully implemented and enforced to ensure representative data is acquired.

The most useful set of gauging data to create a representative cumulative distribution can be achieved by eliminating the erroneous values. A Weibull curve fit to this data set is then ready to be used to improve statistic evaluations (see Figure 9).

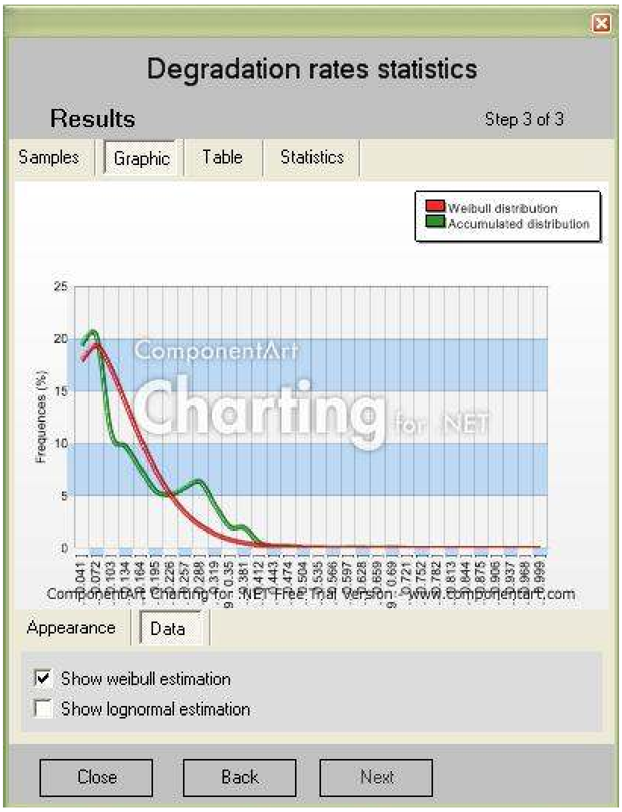

Figure 9: Weibull fit to positive data.

Figure 9 is very close to what other authors [3] have published as in Figure 10.

3.2 STATISTICS

Some authors prefer to use lognormal fits but we have obtained better results by using Weibull. By comparing the fit shown in Figure 9 to the one in Figure 11 we can conclude that the Weibull curve is visually much closer to the actual data.

However, lognormal results in this case result in a lower standard deviation. By comparing the estimated corrosion rate to a given 99% probability we achieve 0.28mm/year for lognormal compared to 0.36mm/year with Weibull. See Figures 12 and 13.

We can conclude that standard deviation should not lead to its choice as the best representation of the corrosion rates since it leads to a less conservative figure. Visual evaluation should also be applied in the selection of the best fit.

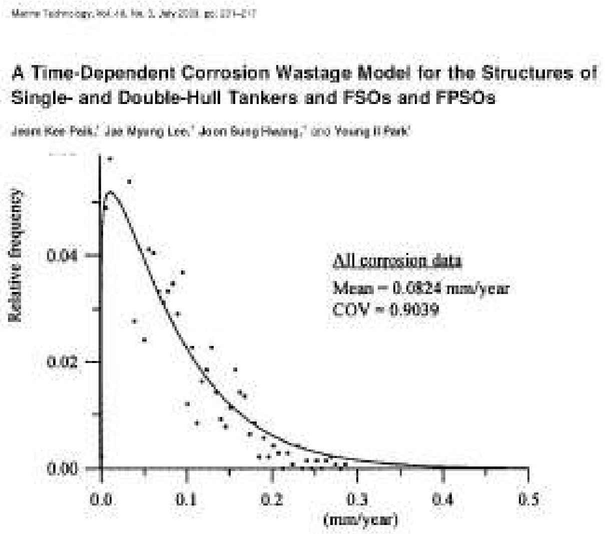

Figure 10: Extracted from Marine technology, Vol. 40, No 3, July 2003, pp 201-217

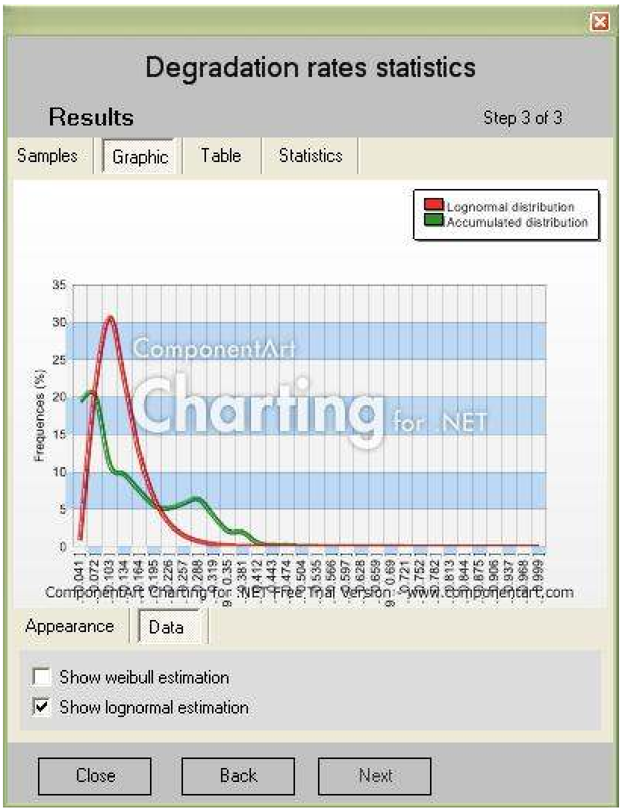

Figure 11: Lognormal fit to same data as Figure 9.

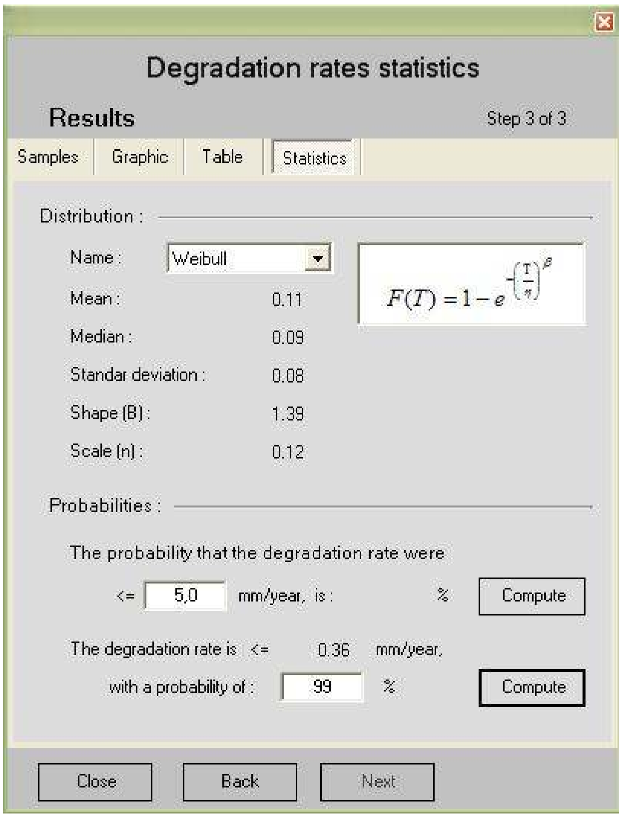

Figure 12: Statistics obtained with Weibull fit

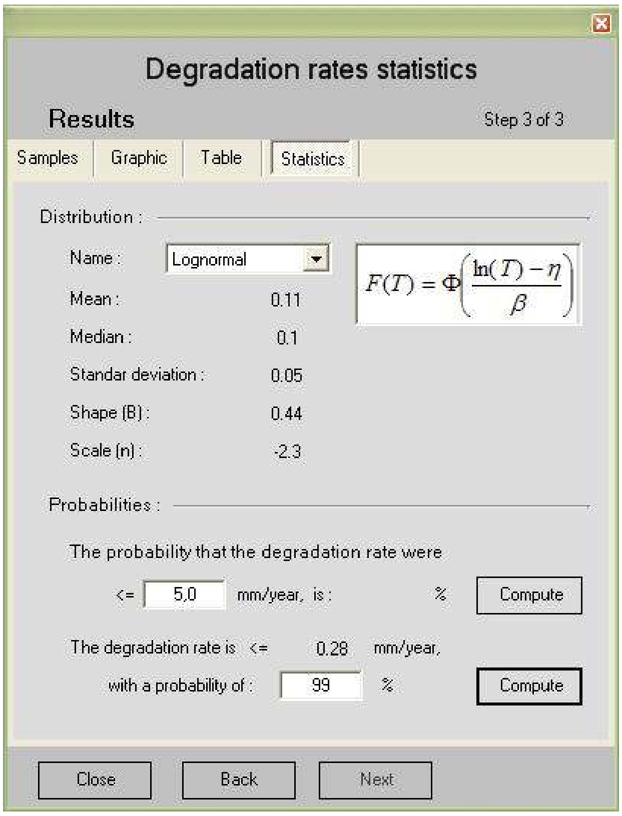

Figure 13: Statistics obtained with lognormal fit

4. IMPLEMENTATION

4.1 MODELLING

We paid a price pioneers often pay, by remodelling the ships and rigs twice. First we built them in 2D and then later in 3D as the software developed. Building a 3D model from a set of 2D sections is not a simple matter of assembly due to the typically lower accuracy of 2D models. It is therefore necessary to redraw many sections not accurate enough to fit the 3D model or that were expanded in 2D. These have to be re-built with the appropriate shape in 3D.

The software was initially designed for 2D, not owing to programming language limitations (despite the challenge of DOS development of such graphic applications) but mainly because users were used to manipulating 2D drawings.

We later recognised however that the 2D interface was well accepted by those involved in ship maintenance but not so well by those in charge of offshore rigs. One reason was because some users do not have naval architecture backgrounds and thus are not used to shell expansions and orientation according to frames. In fact some are not used to terms like substantial corrosion, excessive corrosion or reassessment. Note that offshore rigs are not obliged to have classification and so operate in a different culture.

The 3D interface became established as the best choice due to the increasing use of 3D mock-ups and CAD drawings. Engineers soon came to accept this and even those used to expansions are comfortable with 3D representations.

Most FEM models are built by engineers but building 3D models for maintenance and integrity purposes represented a challenge due to the large amount of repetitive work. However draftsmen usually do not have the necessary skills to build an accurate model. Using a combination of skills was therefore the best choice and resulted in robust models.

From the outset we decided not to build features into the software to allow 3D modelling but instead to use regular 3D CAD software like AutoCAD or Micro Station. It proved to be a perfect choice and avoided many potential problems. End users do not want to build models but just gather information about the degree of degradation, level of risks or building repairs.

It takes around 1400 man hours to build an FPSO or ship model. Jack-up rigs take around 500 man hours. Semi-submersible rigs are close to FPSO's in terms of resources required.

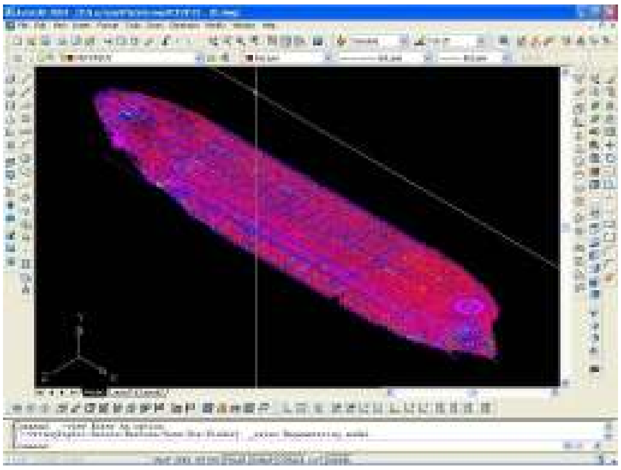
Figure 14: 3D model built in CAD software.

4.2 DATA INPUT

The degradation gauging is fed into the model in order to allow effective uses like calculating corrosion rates.

Besides gauging we also insert into the model past repairs, original drawings, modelling reports, reassessment reports and pictures.

Inputting gauging information is straightforward and can be done by any user familiar with the geometry of the structure being used.

The main challenge has been to understand the different sketches produced by gauging companies in their reports despite the use of IACS standards.

Some companies are using the sketches produced by PHDC4D and in doing so the process becomes much faster, since there is no interpretation to be done before data input.

The first time data is input can take longer if the user wants to use all existing information. Provided reports are clear then in our experience it is possible to input around 1000 gauging points per day per person.

As stated previously, the gauging companies could and should do this work to improve efficiency and reduce costs for the customer. The software has the capability to acquire data directly from gauging equipment. However thickness gauging companies would need to be trained to understand the situations that lead to points being gauged more than once. If they could input the points the same day we believe that errors could easily be avoided. By marking some key points they could assure the appropriate sequence had been loaded into the model.

We have been successfully working with a number of gauging companies that are quickly learning to use the software.

4.3 USER TRAINING

Users typically want to undertake short courses to understand the basics but struggle to find time to go deeper into the more sophisticated features. Most learning has consequently been conducted on the job.

Nevertheless, the learning curve seems to be fairly short, mainly for those used to Microsoft Office interface since we adopted a similar look and feel.

Robust support and a user-friendly interface are critical to the success of this type of software. Otherwise users will never use it to its full potential.

5. RESULTS ACHIEVED

The technology incorporated into the software has been shown to reduce by 50% the cost required to renew steel on a VLCC.

By extrapolating old gauging data to achieve a better mapping of the corroded areas we were able to raise the accuracy of the forecast steel renewal figure. The client was therefore able to predict the budget required ahead of time more accurately.

We subsequently had two cases in which we helped to avoid a tanker's repairs to continue regular operation. Due to the large amount of steel renewal that would be necessary the hulls were converted to FPSOs instead.

Use of the software also allowed a ship owner to anticipate a request for Classification Societies to use FEM criteria to produce reassessments. This reduced by half the amount of steel renewal required.

PHDC4D allowed users to realise the poor quality of some thickness gauging reports and take actions to improve accuracy.

Besides the primary applications for the software such as identifying areas of greater risk or those with higher corrosion rates, the models were also used to aid knowledge management for all structure-related issues. This replaced the existing management systems for this information. The models became the database for risk-based inspection procedures adopted by Petrobras.

The sharing of information through the software between ship and rig owners with Classification Societies' consulting branches and gauging companies has been made possible through a common interface. Petrobras has hired the consulting branches of major Classification Societies to develop and update the many different models to assure the safety of offshore rigs including stability, hydrodynamics, FEM and degradation. For stability they developed their own software to keep a common interface for all rigs. The same approach has been used for degradation information by using the single interface provided by PHDC4D with the various Classification Societies involved.

There have been no major structural incidents with Transpetro tankers during the 13 years they have used this technology. In part this is due to a broader set of good practices being implemented such as better control of structure integrity status through the use of PHDC4D.

6. FUTURE BENEFITS AND DEVELOPMENT

We have implemented painting features to help track paint rust, calculating blasting areas, paint volumes and regions to paint (see brown painting areas in Figure 15). So far this capability has not been widely used with the exception of the blasting area calculation. Once users verify the benefits and begin to use this facility we believe painting control will be more accurate.

Figure 15: Jack-up rig with painting areas in brown and inserted construction drawings.

We have not yet solved the pitting issue associated with hulls. Even by keeping track of the pitting found during inspection our customers had some problems with pitting not identified during inspections. We can predict the corrosion progress by fitting curves to historic thickness gauging data and so prioritise inspections and repairs, but we are not able to foresee when previously undetected pitting will cause a leak in the hull.

The software is able to keep track of cracks but this feature has not been used to date. This is probably because once the cracks are found they are immediately repaired. However, we believe that if this information were acquired then it could improve maintenance of sister ships.

PHDC4D allows the input of any kind of document such as survey reports, photographs, schedules and others (see inserted icon and pop up drawing in Figure 15). However such functionality has typically been used only for the initial modelling when we insert construction drawings and reassessment reports. The subsequent survey reports and photographs were not fed into the model.

7. TECHNOLOGY STANDARDISATION

A number of other organisations developed products with similar goals such as the American Bureau of Shipping's Safenet Hull Maintenance Module (see Figure 16), Det Norske Veritas' Hull Life Cycle Manager (see Figure 17) and Germanischer Lloyd's Pegasus (see Figure 18).

Similar approaches have been used by these solutions applying the same principle as the Classification Rules. These had to be standardised according to IACS common structural rules, as explained in the following text extracted from the IACS web site.

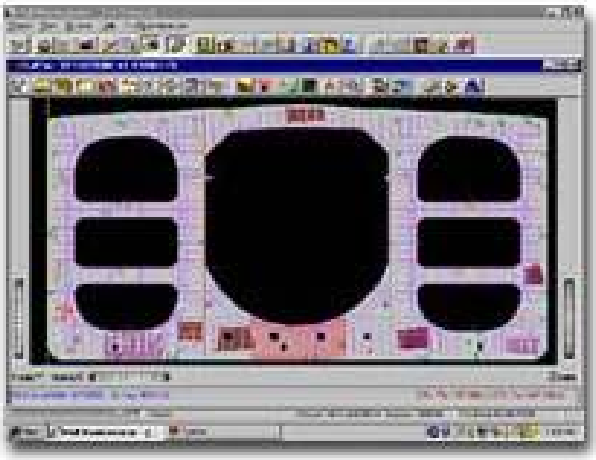

Figure 16: ABS Safenet Hull Maintenance Module. Extracted from www.abs-ns.com/products/fleet/hull.html

"On 14 December 2005 the Common Structural Rules for Tankers and Bulk Carriers were unanimously adopted by the IACS Council for implementation on 1 April 2006. The Council was satisfied that the new rules have been based on sound technical grounds, and achieve the goals of more robust and safer ships….

IACS now implements the CSR maintenance program (IACS Procedural Requirement No.32) via the IACS CSR Knowledge Centre (KC). All the agreed Q&A's and CIs (Common Interpretations) are published on the IACS web site without delay in order to assist its Member Societies and Industry in implementing the CSR in a uniform and consistent manner."

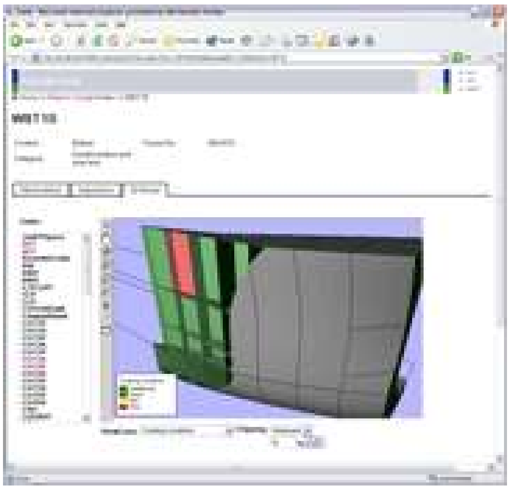

Figure 17: Hull Life Cycle Manager. Extracted from www.dnv.com/software/assetIntegrity/HULCgallery.asp

It took some time for the rules to be standardised and we believe there should not be the same delay for hull maintenance software. The sooner standards are established, the sooner the industry can benefit from a common interface. Establishing a common database format but still requiring a user to have deal with multiple different interfaces according to the classes of their fleet is not desirable.

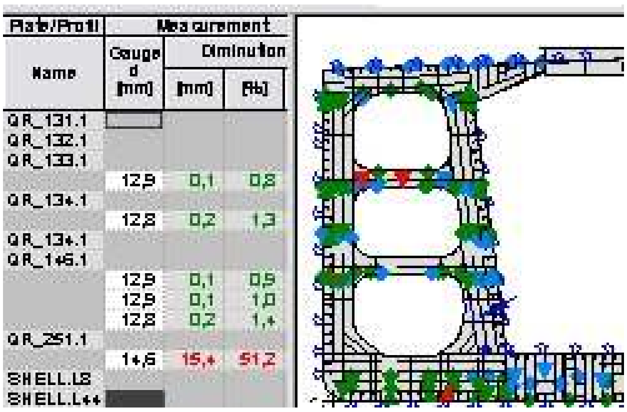

Figure 18: GL Pegasus. Extracted from www.gl-group.com/maritime/fleet/10401.htm

Ideally broader development cooperation should be realized to facilitate faster development and interface standardisation.

8. CONCLUSIONS

The third generation of PHDC4D technology is now sufficiently mature for large-scale application.

Building models and inputting data is a long-term process. Addressing differences between emerging technologies represents the next big challenge. We experienced these issues while the software was under development with models having to be adapted to reflect changing technology. The software development process therefore has to be sufficiently flexible to address evolving technology and successive model changes.

Closer cooperation to create standards among those developing similar technologies would help the industry to operate ships and rigs more safely.

Manually generated TM Reports as defined by IACS standards are obsolete and adapting software to produce those reports automatically should be achieved in the near future. We recommend that IACS rethink how reports are produced in light of the new technology now available.

It is now possible to record and act on valuable information detailing the full set of gauging data rather than just the average values.

9. ACKNOWLEDGEMENTS

This research has been supported by the following Brazilan agencies: Finep, CNPq and Faperj.

The author also wishes to thank Transpetro, Petrobras, Modec and Shell for their incentive, resources and interaction that allowed us to develop this technology.

10. REFERENCES

1. D. M. Ribeiro and C.H. Albrecht, 'Sistema Integrado de Manutenção do casco do Navio', SOBENA, 1994
2. D.M. Ribeiro and C.A.R. Correia, 'A Experiência de Cinco Anos de Aplicação de um Software de Manutenção Estrutural", SOBENA, 2000
3. Jeom Kee Paik, Jae Myung Lee, Joon Sung Hwang and Young Il Park, 'A Time-Dependent Corrosion Wastage Model for the Structures of Single- and Double-Hull Tankers and FSOs and FPSOs', Marine Technology, Vol. 40, No. 3, July 2003, pp. 201–217

11. AUTHORS' BIOGRAPHIES

Duperron Marangon Ribeiro holds the current position of Professor at the Federal University of Rio de Janeiro and CEO of PhDsoft.