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AVOIDING DISASTERS: EVOLUTION IN INTEGRITY AND MAINTENANCE MANAGEMENT

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ABSTRACT

The critical structure demands a 3D model to recreate a real situation and optimize the asset maintenance with a visual management. Since 1995, Petrobras uses software able to do the maintenance management registering the structures degradation evolution, paints, and cathodic protection in all vessels and offshore platforms. This paper regards how technology can help to avoid disasters with timeline deployed information management applied to structure maintenance.

1. INTRODUCTION

The critic structural asset integrity, in general, can be harmed by excessive corrosion and a maintenance management deficiency. In the U.S. the direct costs associated with metallic corrosion is approximately 3.2% of the U.S. Gross Domestic Product [(1)]. Rust is one of the most common causes of failures in the civil area; it can lead a structure to collapse or spall, creating several problems. In Brazil, the corrosion costs for the oil and gas market is around US$ 10 billion.

In the maritime industry, ship hull failures and lack of integrity equipment maintenance are the principal causes of oil spill disasters. The maintenance regime for such structures involves periodic inspections to assess condition by observations and measurements - with the aim of monitoring corrosion, cracking and coating deterioration. Traditional records of inspections rely on paper-based reports and mark up of drawings - a method that may not ensure a high-quality, reliable and effective management system. It is estimated to reduce costs to even 30% with a higher and better corrosion control [(1)], when costs in a single repair may achieve more than one billion dollars [(5)].

In the refinery and process plant industry, static equipment such as pressure vessels, pipes, tanks and general structures are responsible for 75% of large losses caused by mechanical failures [(2)].

2. MAINTENANCE SOFTWARE

C4D® is a software solution continuously developed by a Brazilian company called PhDsoft, founded in 2000, with the purpose of providing structural maintenance by integrating and automating the management process – failures, pollution or casualties beyond the 4th dimensional. Petrobras, Transpetro, Shell, Modec, among other companies use C4D® on ships, vessels and offshore platforms for building, maintaining and interacting with temporal-geometric models of a structure through an intuitive, graphically driven user interface that simplifies the complex 4th dimensional data management process.

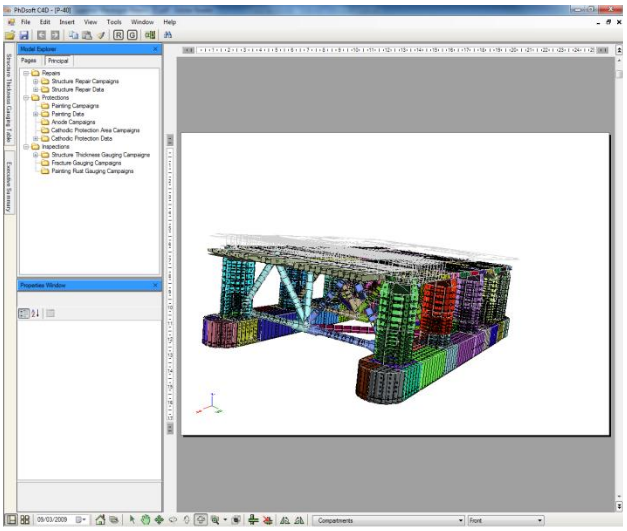


Figure 1 – Offshore Platform Model

By maintaining an up-to-date status of structure condition with a comprehensive history of inspections and repairs, C4D® simulates deterioration processes to predict future condition -

allowing maintenance actions to be planned and executed effectively.

2.1 Structure Integrity

Inspection methods are necessary to insure the structure integrity. Every critical region should be identified and evaluated following the standards. A single inspection of an offshore platform can collect countless information and may take time to evaluate the structure integrity. All the measured thicknesses and any related file from an inspection can be stored in software on the exact position and time, helping the knowledge management. With software providing visual information it is possible to optimize the next inspection plan. In a unique screen it is possible to do overall evaluation of the assets.

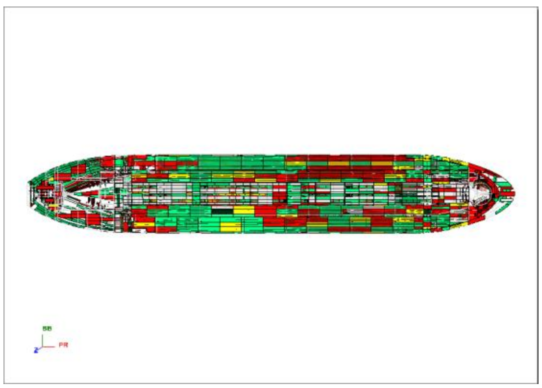


Figure 2 – Degradation Tracking

Software has a standard color scale for quick evaluation (Fig. 2):

- Green for admissible corrosion
- Yellow for substantial corrosion
- Red for excessive corrosion

This information can be added manually by inserting measured points or even integrated from ultrasonic inspection equipment.

2.2 Corrosion Evolution

The corrosion rate is the basic level criteria for a maintenance decision. This criterion was implemented so that the software will suggest by itself critical areas for replacement. This optimizes the decision process avoiding unnecessary substitutions and compromised areas without repairs.

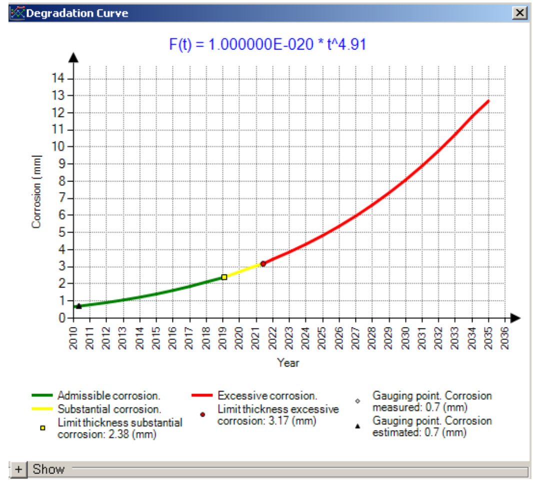


Figure 3 – Degradation Curve

By doing statistic calculations, C4D® generates degradation curve (Fig. 3) using inspected information, to help with the evaluation of the structure conditions and do maintenance by performance. Following several restrictions such as number of measures, type of material, compartment loadings and location of the structure a degradation curve is extrapolated to comprehend the corrosion tendencies.

To answer questions about degradation rates probability, a small statistic wizard is available. To perform a statistical analysis it is necessary to have stored some inspections samples.

Two types of probability distributions are available:

Weibull distribution:

$$F(T) = 1 - e^{-\left(\frac{T}{\eta}\right)^{\beta}}$$

Log-normal distribution:

$$F(T) = \Phi\left(\frac{\ln(T) - \eta}{\beta}\right)$$

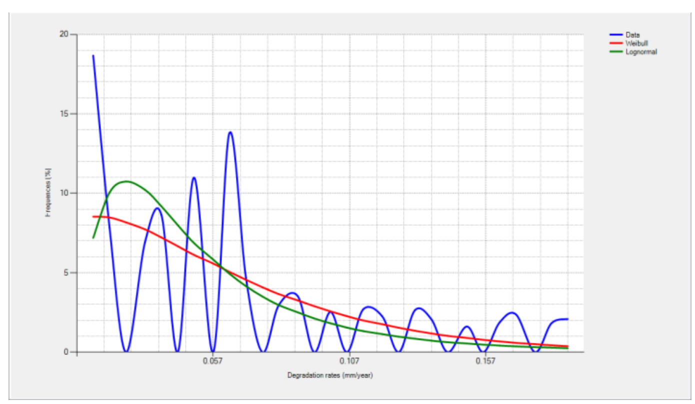
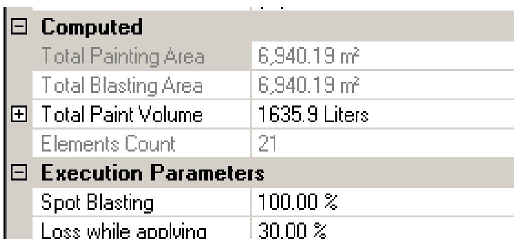


Figure 4 – Frequencies by Degradation Rates

2.3 Painting tool

Another feature is C4D® painting tool, in an interactive 3D model by highlighting compartments, elements or areas. It will easily give the total paint volume by following paint schemes stored in the database and a paint scope defined by the user. It provides the exact amount of paint needed for all the highlighted involved structures. Fig. 5 is an example of a FPSO painted compartment. In a few steps the software calculated the total painting area and paint volume.



Computed	
Total Painting Area	6,940.19 m²
Total Blasting Area	6,940.19 m²
Total Paint Volume	1635.9 Liters
Elements Count	21
Execution Parameters	
Spot Blasting	100.00 %
Loss while applying	30.00 %

Figure 5 – Total Paint Volume

2.4 Cathodic Protection

Cathodic Protection Technique is also a feature in C4D®. To protect from corrosion a constantly immersed metallic material, wizards are included (Fig. 6) to help the user to do the anode dimensioning and positioning for vessels and ships, accelerating the consulting and project works and supporting the technical crew in the anodes gathering and installations. This tool allows seeing the project viability, helping on the decision process.

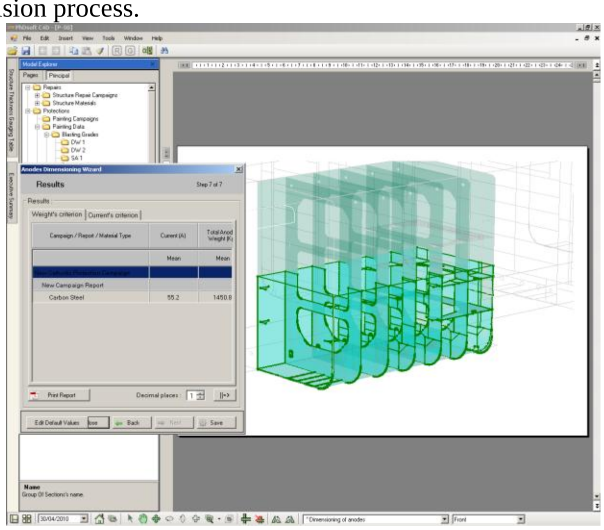


Figure 6 – Cathodic Protection Area

Along these mentioned features, C4D® is a knowledge management solution that facilitates the access of information by storing any kind of document in a single C4D® model file and enabling the timeline information sharing among the asset maintenance collaborative provision chain.

2.5 Api 579 – level 1 Assessments

Beside the maritime industry, C4D® is being developed to refinery, industrial and nuclear plants using the Fitness-For-Service (FFS) assessments in API 579-1/ASME FFS-1. A risk of failure may be present where inspection has revealed degradation and also flaws in the equipment. Those engineering evaluations are performed to demonstrate the structural integrity of an in-service component that may contain a flaw or damage or that may be operating under specific conditions that could produce a failure. The guidelines provided in this standard may be used to make run repair-replace decisions to help determine if pressurized equipment containing flaws that have been identified by inspection can continue to operate safely for some period of time.

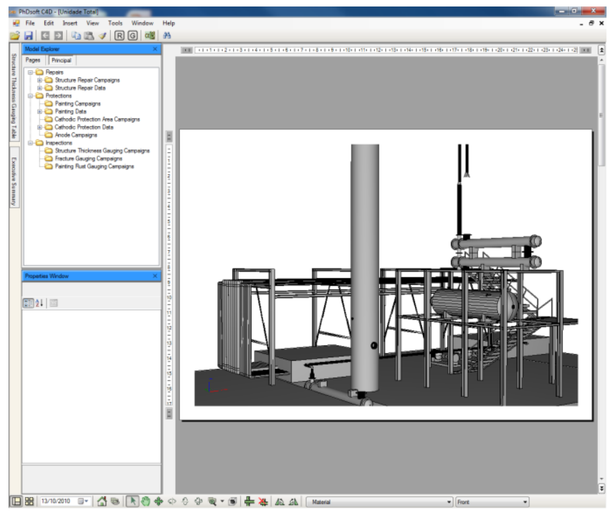


Figure 7 – Refinery model

C4D® is including several applications automating the assessments for brittle fracture, general metal loss, local metal loss, pitting corrosion, blisters and laminations, weld misalignment and shell distortions, crack-like flaws, creep regime operation and fire to extend the life time from the components integrity management. The implementation of models in C4D® can be done by a simple import from original PDMS files to C4D® graphic platform or even from 3D scanners available in the market, without wasting time.

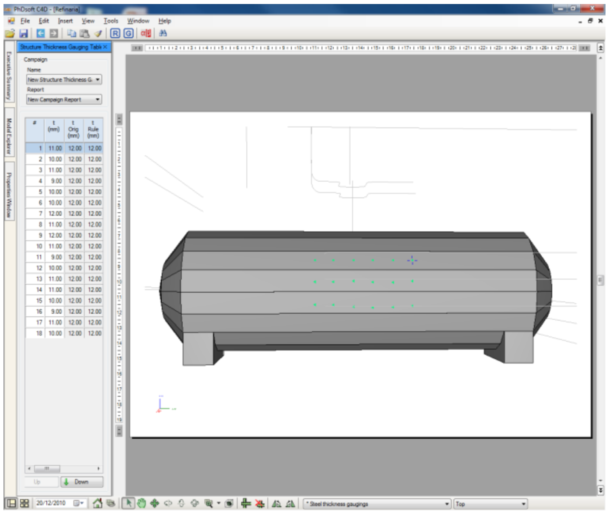


Figure 8 – Highlighted Pressure Vessel

General Metal Loss Part 4 example from Fig 8:

This is a very conservative assessment; “general” implies uniform metal loss with minimum variation of metal loss.
It is generally accepted that extensive pitting is one example of general metal loss.

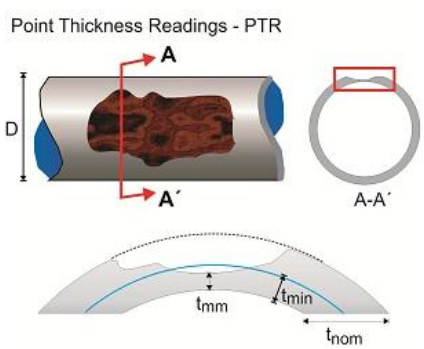


Figure 9 – General Metal Loss

Where:

t_{min}: Minimum Required Thickness
t_{nom}: Nominal Thickness
D: Inside Diameter
FCA: Future Corrosion Allowance
t_{mm}: Minimum Measurement Thickness
t_{am}: Average Measured Thickness
stm: Standard Deviation
covt: Coefficient of Variation
MAWP: Maximum Allowable Working Pressure

#	t (mm)	t Orig (mm)	t Rule (mm)
1	11.00	12.00	12.00
2	10.00	12.00	12.00
3	11.00	12.00	12.00
4	9.00	12.00	12.00
5	10.00	12.00	12.00
6	10.00	12.00	12.00
7	12.00	12.00	12.00
8	11.00	12.00	12.00
9	12.00	12.00	12.00
10	11.00	12.00	12.00
11	9.00	12.00	12.00
12	10.00	12.00	12.00
13	11.00	12.00	12.00
14	11.00	12.00	12.00
15	10.00	12.00	12.00
16	9.00	12.00	12.00
17	11.00	12.00	12.00
18	10.00	12.00	12.00

Figure 10 – Point Thickness Readings

Input Data:

Equipment: Vessel Pressure
TAG: VP-00000
Material: SA 516 Grade 70
Design Condition: 3,7 MPa @ 340^{o}C
Weld Joint Efficiency: 1,0
FCA = 2,00 mm
t_{nom}: 12,00 mm
D: 508,00 mm
Point Thicknesses Readings (Fig.10)

Output Data:

t_{am}: 10,44 mm
covt = 0,088
LOSS = 5,56 mm
t_{min} = 8,17 mm
MAWP: 3,82 MPa

Assessment Results:

The equipment is acceptable per Level 1 criteria.

t_{am} – FCA >= t_{min} (OK)
t_{am} – FCA = 8,44 mm and t_{min} = 8,17 mm

t_{mm} - FCA >= MAX[0.5 * t_{min}, t_{lim}] (OK)
t_{mm} - FCA = 7,00 and Criterion = 4,09
t_{lim} = MAX[0.2 * t_{nom}, 2.5] = 2,50

3,82 MPa > 3,7 MPa (OK)

The equipment has been accepted on the most conservative part

4 restrictions. A report will be stored on the software database.

3. INTEGRATIONS

C4D® development process permits integrations in order to maximize its use in all abroad maintenance and inspection services.

3.1 ROV Integration

An example is integration with ROV's. Since we aren't able to determine the exact position of the ROV, C4D® has a trust full 3D model replication of the platform. The ROV position is identified on the software by the ultrasonic sensors, sending directly the thicknesses information. Having these, the software replicates on the 3D model in real time, the exact position of the ROV, as shown on Fig.11. This feature allows to identify precisely in vessel's hulls pitting's, avoiding oil spills due to holes in the structure.

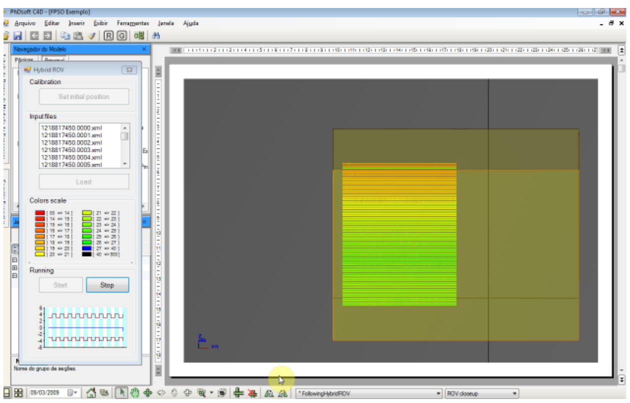


Figure 11 – ROV Position Replication

4. CONCLUSION

Problems may be avoided by predicting any future situation, when it is possible to detect and minimize any repair costs. Several structural failures were avoided and the consequent large-scale leaks through the assessment of possible future scenarios. The structural integrity is helped by a constant corrosion monitoring and any other maintenance actions achieved on the asset. It is recommended for an asset owner to have a visual solution to follow all the asset life cycle. This kind of technology has very significant results in the cost and risk reductions for the offshore platforms.

FFS assessments are performed to demonstrate the structural integrity of an in – service process equipment. Including API 579 standards, C4D® will help any process decision in refinery, petrochemical, nuclear and any process plant industries.

In summary, C4D® - an integrated IT environment - organizes data facilitating actions in the present to assure proper structure maintenance, avoiding risks in the future, as a solution that promotes a knowledge management and sustainable ecological development.

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