Extending the Service Life of Ageing FPSO and SPM Calm Buoy Under Corrosion Effects: A Case Study on Hull and Deck Plate

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CMD 2026 – SCIFORUM - 176514

INTRODUCTION & AIM

The floating production, storage and offloading (FPSO) and single point mooring (SPM) calm buoy represents a new technology with a promising future in the upstream oil and gas industries. They are usually designed for 20 years' operational life depending on field life/oil reserves. The FPSOs are usually new build or converted tanker while the SPMs are usually new built or refurbished buoy. They are generally installed in harsh environments. However, several challenges came up which are of both industry and academic interest. The hull and deck plates of the FPSOs and SPMs are exposed to corrosive actions of seawater which over time results to wastages due to general/uniform or pitting corrosion. Several measures such as risk based inspection (RBI) programs are put in place by the owner/operator alongside a class society covering such asset to enable it serve the design operational life. The data obtained from such RBI programs are used to drive maintenance strategies on the FPSO and SPM calm buoy. The class societies also put in place yearly annual health checks, annual class and statutory surveys which are assurance programs designed to sustain FPSOs and SPMs throughout their design services life. These programs also sustain the well-known certificate of class which is renewable every five years. Interestingly, some operators might decide to operate the FPSOs and SPMs beyond their design life in what is called life extension. Life extension studies is gradually dominating the coast of West Africa, while the rest of the world is not left out. This present study provides the required understanding, collation and interpretation of surveillance data that drives mitigation strategies such as weld infill, crop and weld, additive patch, protective paint coating, sandwich plate systems on ageing and structural health issues on hull and deck plates which in turn drives life extension repairs decisions on floating assets. The research work focussed on structural health challenges such as corrosion wastage on FPSO and SPM hull and deck plates. Thus, historic data collection, their collation, interpretations and managements were found useful towards life extension project delivery. It was noted that due to increasing scarcity of field data, most of the research works in fatigue assessments, structural health monitoring, structural reliability and life extension of FPSO and SPM calm buoy hull and deck plates, leveraged on data obtained from trading/shuttle tankers and corrosion coupon in laboratory and extend it to life extension studies of FPSO and SPM, this constitutes an empirical research gap. Such data from laboratory are unreliable because they are under control unlike data from the field locations in marine environment, where corrosion wastages occurs naturally. Also, the data from trading tankers are unreliable because they are exposed to different international waters with diverse corrosion wastage rates. Trading tankers are built with thicker scantlings. Thus, field data were recommended by previous researchers for subsequent FPSO and SPM calm buoy hull and deck plates corrosion wastage assessments. This present work unveils a case study on the structural integrity management of an ageing FPSO and SPM calm buoy, with a primary focus on the degradation effects of corrosion. Historically, as FPSO and SPM calm buoy exceed their initial design life, the menace of corrosion wastages poses a significant threat to structural reliability, particularly in critical areas such as the hull and deck plates. The paper presents a comprehensive assessment methodology involving in-service surveys data, corrosion wastage computations, and structural reassessment to evaluate the remaining thickness of these components which is a measure of the remaining strength. A software named HULL-LIFE was developed to evaluate the FPSO and SPM calm buoy hull suitability for life extension of 15 years. This program reduces time spent in data processing and makes hull and deck plates repairs decisions easier and ultimately life extension. The program is handy in establishing if the hull is fit for a certain number of years of extension. This present work further provides a frame work for assessing the structural integrity and suitability of FPSOs and SPMs for a life extension with specific focus on corrosion effects. This frame work will help to quantify the impact of corrosion on the FPSOs and SPMs structural capacity and further provide a rational basis for FPSO and SPM life extension decisions. Thus, ensuring continued safe and reliable terminal operations beyond the original designed service life. The aim of the research is extending the service life of ageing FPSO and SPM calm buoy under corrosion effects: a case study on hull and deck plate.

METHOD

FPSOs and SPMs are generally installed in harsh environments which undoubtedly exposes them to the menace of corrosion wastages, structural degradations and deteriorations. This research work recognized corrosion wastages as primary deterioration mechanism for ageing FPSOs and SPMs which served as case study in this research. This work applied real marine environment corrosion wastage data obtained from offshore terminal location such as remaining thickness measurements as the building blocks of its analysis. As per class societies rules, requirements and recommendations, by substituting these empirical data into structural health monitoring (SHM) and structural reliability analysis (SRA) models, this research work evaluates the present structural conditions of both hulls and deck plates to establish their fitness for continued use and additional life of 15 years. This research paper summarized a framework for life extension assessment of FPSO and SPM calm buoy hull and deck plates by integrating SHM and SRA. These field empirical data were used to test probabilistic equations of corrosion degradation and deteriorations, thus shifting from traditional code checks to quantify the long term structural reliability of critical components such as the hull and deck plates.

$$\text{Year life extension} = (\text{year end of life extension} - \text{year end of design life}) \quad (1)$$

Class wastage allowance is given by:

$$\text{The corrosion margin life extension} = \begin{Bmatrix} Corrosion\ rate\ design * (year\ life\ extension - year\ coating\ protect), if\ coating\ renewed > 0 \\ Corrosion\ rate\ design * year\ life\ extension, otherwise \end{Bmatrix} \quad (2)$$

$$WA = WA_{class} \quad (3)$$

$$t_{design} = \begin{Bmatrix} t_{reassessed}, if\ treassessed < t_{as\ built} \\ t_{as\ built}, \quad otherwise \end{Bmatrix} \quad (4)$$

$$t_{renewal} = t_{design*(1-WA)} \quad (5)$$

$$t_{substantial} = t_{design*(1-0.75\,WA)} \quad (6)$$

$$t_{\min life\ extension} = (t_{substantial} + Corrosion\ margin\ life\ extension \quad (7)$$

$$t_{end\ of\ design\ life} = t_{avg\ gauged} - Corrosion\ rate\ design \begin{pmatrix} year\ end\ of\ design\ life \\ - \\ year\ gauged \end{pmatrix} \quad (8)$$

$$Plate\ renewal\ required = \begin{Bmatrix} "NO" t_{end\ of\ design\ life} > t_{\min life\ extension\ built} \\ "YES", Otherwise \end{Bmatrix} \quad (9)$$

The average of the UTM gauging points is expressed as:

$$Average = \frac{U_1 + U_2 + U_3 + U_4 + \ldots + U_n}{U_n} \quad (10)$$

RESULTS & DISCUSSION

The results from this work quantified the effects of corrosion wastages on ageing FPSO and SPM hull and deck plate. The results were obtained from UTM conducted on an FPSO and SPM in 2023 barely 18 years in service and 2 years to end of design service life. The FPSO operates in a shallow water of Offshore West Africa. The data obtained was collated and analysed to make mitigation strategies decisions on the deck plates with the ultimate goal of life extension. Similarly, the hull of both FPSO and SPM was examined using corrosion models to ascertain suitability for 15 years life extension. The results were favourable since the value of t-end of design life is greater than t-minimum for life extension. Hence, no steel plate renewal is required on the hulls of the FPSO and SPM calm buoy. This was made possible by a software code named HULL LIFE written in C++ programming language. This approach further underscores the application of SHM data in SRA framework to oversee FPSO and SPM maintenance planning and mitigation strategies aimed at longevity and life extension. Thus, for the FPSO hull, since 20.1112 mm is greater than 19.783 mm, it means that the FPSO hull will serve for the intended 15 years. Thus, the hull is adequate for additional 15 years in service. Similarly, for the SPM calm buoy hull, since 11.73 mm is greater than 9.725 mm, it means that the SPM calm buoy hull will serve for the intended 15 years extension. Thus, the hull is adequate for 15 years life extension. For the FPSO main deck plates wastage assessments, the highest values fall within 21 -36% and the few affected strakes were recommended for crop and renew as a mitigation strategy. For the SPM calm buoy, the top plates wastage evaluations showed a reduction in the range of 4 – 6%; while that of floor plate showed 1- 4% thickness reduction and application of new surface coating were recommended.

Table (1): FPSO Main Deck Port Side Pitted Plates Renewal Calculation and Mitigation Strategies

	PortSide									Pitted Plates Renewal Calculations								
	Strake	As built Thk.	UTM Gaugings (mm)					Average Gauged Thk	Minimum Gauged Thk	Pits Depths (mm)					Max Pit Depth	Diminution	Recommended Pit Repairs Required
Frames	(Zones)	(mm)	1	2	3	4	5		(mm)	1	2	3	4	5	(mm)	(%)	
	1	16.00	12.60	12.65	12.65	12.55	12.55	12.60	12.55	3.40	3.35	3.35	3.45	3.45	3.45	21.56	Crop & Weld/Renew Required
45	2	16.00	12.36	12.37	12.45	12.38	12.44	12.40	12.36	3.64	3.63	3.55	3.62	3.56	3.64	22.75	Crop & Weld/Renew Required
	3	16.00	12.40	12.20	12.30	12.30	12.28	12.30	12.20	3.60	3.80	3.70	3.70	3.72	3.80	23.75	Crop & Weld/Renew Required
44	4	16.00	10.50	10.35	10.48	10.45	10.51	10.46	10.35	5.50	5.65	5.52	5.55	5.49	5.65	35.31	Crop & Weld/Renew Required
	5	16.00	10.20	10.23	10.21	10.13	10.20	10.19	10.13	5.80	5.77	5.79	5.87	5.80	5.87	36.69	Crop & Weld/Renew Required
43	6	16.00	13.60	13.60	13.61	13.54	13.65	13.60	13.54	2.40	2.40	2.39	2.46	2.35	2.46	15.38	Additive Patch (Epoxy & Coating Required)
	7	16.00	13.34	13.25	13.30	13.30	13.30	13.30	13.25	2.66	2.75	2.70	2.70	2.70	2.75	17.19	Additive Patch (Epoxy & Coating Required)
42	8	16.00	13.16	13.22	13.21	13.21	13.22	13.20	13.16	2.84	2.78	2.79	2.79	2.78	2.84	17.75	Additive Patch (Epoxy & Coating Required)
	9	16.00	13.60	14.40	14.20	13.80	14.00	14.00	13.60	2.40	1.60	1.80	2.20	2.00	2.40	15.00	Additive Patch (Epoxy & Coating Required)
41	10	16.00	14.00	13.20	13.75	13.50	13.50	13.59	13.20	2.00	2.80	2.25	2.50	2.50	2.80	17.50	Additive Patch (Epoxy & Coating Required)
	11	16.00	14.65	15.30	15.50	15.00	14.20	14.93	14.20	1.35	0.70	0.50	1.00	1.80	1.80	11.25	Additive Patch (Epoxy & Coating Required)
40	12	16.00	13.80	14.00	13.90	13.20	13.80	13.74	13.20	2.20	2.00	2.10	2.80	2.20	2.80	17.50	Additive Patch (Epoxy & Coating Required)

Table (2): FPSO Main Deck Port Side Average Wastage Steel Renewal Calculation and Mitigation Strategies

	PortSide		Average Wastage Steel Renewal Calculations						
	Strake	As built Thk.	Ave. Gauged Thk	Diminution	Ave. Wastage (Diminution)	ABS Wastage Allowance	T. Renewal	T. Substantial	Repairs Recommendation
Frames	(Zones)	(mm)	(mm)	(mm)	(%)	(%)	(mm)	(mm)	
	1	16.00	12.60	3.40	21.25	20.00	12.80	13.60	Crop & Weld/Renew Required
45	2	16.00	12.40	3.60	22.50	20.00	12.80	13.60	Crop & Weld/Renew Required
	3	16.00	12.30	3.70	23.15	20.00	12.80	13.60	Crop & Weld/Renew Required
44	4	16.00	10.46	5.54	34.63	20.00	12.80	13.60	Crop & Weld/Renew Required
	5	16.00	10.19	5.81	36.32	20.00	12.80	13.60	Crop & Weld/Renew Required
43	6	16.00	13.60	2.40	15.00	20.00	12.80	13.60	Additive Patch (Epoxy & Coating Required)
	7	16.00	13.30	2.70	16.88	20.00	12.80	13.60	Additive Patch (Epoxy & Coating Required)
42	8	16.00	13.20	2.80	17.50	20.00	12.80	13.60	Additive Patch (Epoxy & Coating Required)
	9	16.00	14.00	2.00	12.50	20.00	12.80	13.60	Additive Patch (Epoxy & Coating Required)
41	10	16.00	13.59	2.41	15.05	20.00	12.80	13.60	Additive Patch (Epoxy & Coating Required)
	11	16.00	14.93	1.07	6.69	20.00	12.80	13.60	Additive Patch (Epoxy & Coating Required)
40	12	16.00	13.74	2.26	14.11	20.00	12.80	13.60	Additive Patch (Epoxy & Coating Required)
	13	16.00	13.39	2.61	16.29	20.00	12.80	13.60	Additive Patch (Epoxy & Coating Required)
39	14	16.00	14.72	1.28	8.00	20.00	12.80	13.60	Additive Patch (Epoxy & Coating Required)
	15	16.00	13.54	2.46	15.36	20.00	12.80	13.60	Additive Patch (Epoxy & Coating Required)
38	16	16.00	14.74	1.26	7.87	20.00	12.80	13.60	Additive Patch (Epoxy & Coating Required)
	17	16.00	14.47	1.53	9.56	20.00	12.80	13.60	Additive Patch (Epoxy & Coating Required)
37	18	16.00	15.40	0.60	3.75	20.00	12.80	13.60	Additive Patch (Epoxy & Coating Required)
	19	16.00	14.50	1.50	9.37	20.00	12.80	13.60	Additive Patch (Epoxy & Coating Required)
36	20	16.00	13.18	2.82	17.60	20.00	12.80	13.60	Additive Patch (Epoxy & Coating Required)
	21	16.00	13.33	2.67	16.67	20.00	12.80	13.60	Additive Patch (Epoxy & Coating Required)
35	22	16.00	15.09	0.91	5.69	20.00	12.80	13.60	Additive Patch (Epoxy & Coating Required)

Table (5): FPSO FPSO and SPM Calm Buoy 15 years life extension hull suitability end results

Hull ID	t-end of design life (mm)	t-minimum for life extension (mm)
FPSO	20.1112	19.783
SPM	11.7300	9.7250

Table (3): SPM Calm Buoy Top Plates Pitted Renewal Calculation and Mitigation Strategies

	SPM Top Pitted Plates Renewal Calculations																
S/N	Description	Strake	As built thickness	UTM Gaugings (mm)					Min Gauged Thickness	Pits Depths (mm)					Max Pit Depth	Diminution	Recommended Pit Repairs Required
			(mm)	1	2	3	4	5	(mm)	1	2	3	4	5	(mm)	%	
1	Compartment	1	10.00	9.40	9.60	9.70	9.40	9.60	9.40	0.60	0.40	0.30	0.60	0.40	0.6	6.00	Removal of Old Coating, Surface Cleaning and Application of New Suitable Coating.
2	Compartment	2	10.00	9.70	9.50	9.60	9.50	9.60	9.50	0.30	0.50	0.40	0.50	0.40	0.5	5.00	Removal of Old Coating, Surface Cleaning and Application of New Suitable Coating.
3	Compartment	3	10.00	9.60	9.60	9.60	9.60	9.60	9.60	0.40	0.40	0.40	0.40	0.40	0.4	4.00	Removal of Old Coating, Surface Cleaning and Application of New Suitable Coating.
4	Compartment	4	10.00	10.00	10.00	9.90	9.90	9.90	9.90	0.00	0.00	0.10	0.10	0.10	0.1	1.00	Removal of Old Coating, Surface Cleaning and Application of New Suitable Coating.
5	Compartment	5	10.00	9.90	9.90	9.50	9.50	9.60	9.50	0.10	0.10	0.50	0.50	0.40	0.5	5.00	Removal of Old Coating, Surface Cleaning and Application of New Suitable Coating.

Table (4): SPM Calm Buoy Top Plates Wastage Steel Renewal Calculation and Mitigation Strategies

	SPM Top Plates Wastage Steel Renewal Calculations													
S/N	Description	Strake	As built thickness	UTM Gaugings (mm)					Ave Gauged Thickness	Diminution	Ave wastage (Diminution)	ABS Wastage Allowance	T. Renewal	T. Substantial	Repairs Recommendations
			(mm)	1	2	3	4	5	(mm)	(mm)	%	%	(mm)	(mm)	
1	Compartment	1	10.00	9.40	9.60	9.70	9.40	9.60	9.54	0.46	4.60	20.00	8.00	8.50	Removal of Old Coating, Surface Cleaning and Application of New Suitable Coating.
2	Compartment	2	10.00	9.70	9.50	9.60	9.50	9.60	9.58	0.42	4.20	20.00	8.00	8.50	Removal of Old Coating, Surface Cleaning and Application of New Suitable Coating.
3	Compartment	3	10.00	9.60	9.60	9.60	9.60	9.60	9.60	0.40	4.00	20.00	8.00	8.50	Removal of Old Coating, Surface Cleaning and Application of New Suitable Coating.
4	Compartment	4	10.00	10.00	10.00	9.90	9.90	9.90	9.94	0.06	0.60	20.00	8.00	8.50	Removal of Old Coating, Surface Cleaning and Application of New Suitable Coating.

CONCLUSIONS

The study presents a comprehensive and technically grounded case study on structural integrity management of ageing FPSO and SPM systems aimed at life extension, with a strong focus on corrosion-induced degradation. The integration of in-service inspection data, corrosion computations, and fitness-for-service assessment provides a robust analytical framework for evaluating life extension feasibility. The development and application of the HULL LIFE program in C++ adds methodological originality and enhances the study's practical relevance. The program out puts shows that for the FPSO hull, t-minimum for life extension is 19.783mm versus 20.111mm being t-end of design life. Similarly, for the SPM calm buoy hull, t-minimum for life extension is 9.725 mm versus 11.730 mm being t-end of design life. The acceptance criteria in each case is that t-end of design life be greater than t-minimum for life extension. The results are clearly articulated, demonstrating that hull structures remain adequate for the intended 15 years of life extension service while identifying critical degradations on deck plate strakes requiring targeted corrosion mitigation and intervention. The emphasis on localized corrosion assessment and risk-based inspection (RBI) represents a significant advancement over conventional uniform corrosion assumptions. The discussion effectively links engineering analysis with operational decision-making and economic considerations, strengthening its industry applicability. The recommendations on inspection strategies, protective measures, and maintenance planning are practical and actionable for offshore terminal operators. Overall, the study contributes valuable insights into sustainable asset management and life extension strategies for ageing offshore infrastructures such as FPSO and SPM calm buoy.

FUTURE WORK/ REFERENCES/ACKNOWLEDGMENT

Future works: Future works should take more case studies and leverage on field data at different regions of the world and offshore locations which is more realistic in FPSO and SPM calm buoy hull corrosion wastage analysis rather than data from trading/shuttle tankers and corrosion coupon in laboratory .

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Acknowledgment:

The authors wishes to acknowledge MDPI publishers and organizers of CMD 2026 conference for giving us the opportunity to present our research work.