Advanced Structural Analysis, Design & Engineering Solutions

Engineering Support Services
Offshore Oil and Gas market: West Africa
Presentation Overview

This presentation provides an overview of the extensive and diverse projects done by Viking Systems in the West Africa Offshore Oil and Gas market. Viking uses a reliable and consistent quality approach to structural assessment of both conversion projects and new vessel designs, in addition to on-going lifecycle management of the structural asset due to corrosion related degradation in strength, as well as changes in structure design resulting from changes in design requirements and equipment upgrades:

- Clients and Projects served over nearly two decades:
  - Oil & Gas (Primarily FPSO and FSO vessels)
  - Military and Defense (Navy, Coast Guard and Patrol Vessels)
  - Commercial (offshore supply, cargo, passenger vessels)
- West Africa Environmental Overview
- Hull Strength Assessment for Offshore Vessels
- Hull Fatigue Assessment for Offshore Vessels
- Special Studies
- Related Professional Reports, Presentations and Industry Editorials
Some of Viking’s Clients

- American Bureau of Shipping (ABS)
- BP, Chevron, ConocoPhillips, Petrobras, Shell, Cobalt
- Modec, Sofec, Mitsui
- Mustang Engineering, Harvest,
- Sembcorp Marine, Maersk Group
- Tanker Pacific Offshore Terminal (TPOT / OMNI)

Design Firms: Oceaneering, Gibbs & Cox, CSC, SAIC, NETSCO, OGI, VARD,
Bristol Harbor Group, LMG Marin

- General Dynamics NASSCO, Bollinger Shipyards,
- Gunderson, Bay Shipbuilding, AKER Philadelphia, Corn Island,
- Alabama Shipyard (BAE), VT Halter Systems
Oil & Gas (FPSO/FSO, etc)

- BP PSVM Angola FPSO
- Cendor MOPU Conversion (Malaysia)
- Chevron Frade FPSO (FEED / 3rd Party Verification / New Module Install)
- Chevron Frade FPSO Redevelopment
- CNR International FPSO Baobab Ivoirien MV10
- Cobalt Cameia FPSO (Angola)
- ConocoPhillips Belanak LPG FSO
- COTCO FSO Kome Kribi 1 (Esso Chad)
- ExxonMobil Yoho FSO
- HESS North Malay FSO
- Kuito FPSO (ABS)
- Petrobras UOTE (External Turret)
- Petrobras FPSO Vidade do Rio de Janeiro MV14
- Petrobras FSO Cidade de Macae MV15
- Petrobras FPSO Cidade de Niteroi MV18
- Petrobras FPSO Cidade de Santos MV20
- Petrobras FPSO Cidade de Angra dos Reis MV22
- Petrobras FPSO Cidade de Sao Paulo MV23
- Petrobras FPSO Cidade de Mangaratiba MV24
- Petrobras FPSO Cidade deltaguai MV26
- Petrobras Cidade de Caraguatatuba MV27
- Petrobras FPSO Cidade de Campos dos Goytacazes MV29
- Shell FPSO Fluminense
- TOTAL Kaombo
- TOTAL PazFlor (DSME)
- Tullow Ghana FPSO Kwame Hkrumah MV21 (Jubilee Field)
- Tullow T.E.N. FPSO Ghana
- 50+ FEED and Proposal Projects

*Denotes West Africa project
Military and Defense

- LCS (Austral Trimaran class of Ships)
- JHSV (Class of Ships)
- LCS (Lockheed Monohull)
- FRC (Class of Ships)
- OPC (Class of Ships)
- MLP (Class of Ships)
- LSD-42 (USS Germantown)
- LSD-43 (USS Ft McHenry)
- DDG-67 (USS Cole)
- DDG-60 (USS Paul Hamilton)
- LHD-6 (USS Bonhomme Richard)
- FFG-36 (USS Underwood)
- LPD-18 (USS New Orleans)
- LSD-47 (USS Rushmore)
- DDG-51 (USS Arleigh Burke)
- DDG-52 (USS Barry)
- DDG-53 (USS John Paul Jones)
- DDG-65 (USS Benfold)
- DDG-102 (USS Sampson)
- CG-66 (USS Hue City)
- CD-56 (USS San Jacinto)
- CG-57 (USS Lake Champlain)
- CG-53 (USS Mobile Bay)
- CG-54 (USS Antietam)
- CG-47 Life Extension
- CG-17 (USS Lake Erie)
- CG-71 (USS Cape St. George)
- Indian Navy Patrol Vessel
- Egyptian Navy Patrol Vessel
- US Navy Submarine Rescue Vessel
- Corrosion Modeling of 30+ CG, DDG, LHD, LSD vessels
Commercial

- Project America Cruise Vessel (STX)
- SeaAmerica Cruise and Conference Vessel (STX)
- Penn Maritime Barge (Alabama Shipyard)
- Penn Maritime Asphalt Barge (Alabama Shipyard)
- Matson CV2600 Containerships (Aker Philadelphia)
- SeaRiver Tanker (Herbert Engineering)
- NASSCO T-AKE Tankers (Herbert Engineering)
- OSG Maritrans Barges
- Corn Island Shipyard Asphalt Barge
- Ocean Residences Under Sea Resort Vessel
- Platform Supply Vessel
- Sergeant Marine Asphalt Commander Double Hull Conversion
- VT Halter Marine Barge Projects
West Africa Environmental Overview

- Benign water conditions means the vessel has extra strength on-site
- Environmental conditions on-site create an opportunity to reduce required steel renewal at conversion more than vessels purposed for other regions (North Sea, GOM)
- Viking is very experienced with ABS, DNV-GL and BV in this region
SAGA Flow Chart:
Hull Strength Assessment for Offshore Vessel
(Class Independent)

Other Loading Software Supported:
- DNV-GL Wasim time domain hydrodynamic software, simulating large amplitude loads
- SAGA Class Rule wave, acceleration and hull girder loading
- SAGA Hydro for Sinusoidal and Trochoidal waves with Froude-Krylov effects included
- SAGA Dynamic Load Parameter Tool
Yielding & Buckling Criteria Checks – Ship Rules & Offshore Rules

SAGA Calculates ABS, DNV, LR, and BV Code Checks

Side Shell Plating Buckling Assessment

Bulkhead Need for Reinforcement

Bottom Stiffener Buckling Assessment to ABS SVR Part 5
Calculation of Optimum Scantlings for Web Stiffeners

- Analysis to determine the ABS Rule minimum scantling requirements for the vertical girders and transverse web frame of all cargo tanks

- The scantlings in way of all main supporting members are checked against inertia and buckling requirements to determine the scantling adjustment and new the minimum FPSO renewal thickness
Tower Mount Structure

A finite model of the pancake truss structure is developed for the study of a DA Tower mount.

Model includes all primary steels of the mount structure as well as the DA Tower support ring, and the section of the DA Tower skirt where it attaches to the support ring.
Structural Naval Architecture and Offshore Engineering

Helicopter Platform Evaluation & Analysis

Global Model Deck Structure

Overall Global Model Loading

Deformed Stress Plot – Critical Scenario
SAGA Flow Chart:
Hull Fatigue Assessment for Offshore Ship
(Class Independent)

Other Fatigue Software Supported:

- SAGA Simplistic Fatigue using stress, probability, and Weibull Distribution
- SAGA Spectral Fatigue using RMS stress and Rayleigh Distribution
- SAGA Spectral fatigue using custom spectrum analyzer and wave spreading
- SAGA Fracture using crack growth calculations
When looking at fatigue for a vessel we consider what the tanker phase has been, route to operating site, and condition while on site.

Global and local FEA models evaluated with spectral fatigue analysis to calculate remaining fatigue life of structural details.

Life extension analyses are conducted for the client’s operating goals at multiple designated lengths of time into the future.
TSS Pipe Rack and HPU Room Stools

Spectral Fatigue Assessment performed on the turret support structure piperack stools, HPU room stools and the entrance house at centerline of converted FPSO

Sub model loaded and solved to develop hull girder deflections

Sub model results screened for fatigue damage using a DNV-D curve and SCF = 2.0

If submodel results show less than required fatigue life, local FEA model with t x t mesh is created for critical details

Local model loaded with enforced displacements from submodel, as well as acceleration loads

Local model element centroidal stress results for fatigue using DNV detail specific curves and SCF = 1.0

If local model results show less than required DFF, local stress results evaluated with hot spot, DNV-D curve, and SCF = 1.0

Outboard Local Model of Stool

SN-Curve Details for Stool
Hawser Reels: Fatigue Assessment

Modification for tanker included spectral fatigue analysis for Hawser Reel allowing for base ship motions, ship loads and usage loads associated with the Hawser
Offloading Station: Fatigue Assessment

Underdeck Reinforcement

Offloading Station Structure Below Main Deck

Mooring Winch Structure Below Main Deck

Typical ship loads combined with local equipment loads when analyzing two bollards and one mooring winch
Crane Foundations: Fatigue Assessment

Spectral Fatigue Assessment performed on the crane pedestal foundation structure and connections to the hull structure of converted FPSO tanker

Model View of Crane in Submodel

Deck IWO Crane Pedestal
Bilge Keel: Spectral Fatigue Assessment

Motion loads and dynamic loads from drag pressure

Case specific: Tanker bilge keel was being removed and a longer, wider bilge keel was to be fitted during conversion to FPSO.
Gangway: Strength Fatigue Assessment

Finite Element Analysis of support hooks and connections to the hull structure

Main Deck Gangway Support Structure Submodel

Yielding Evaluation – Bracket at Side Shell

Local finite element model of the main deck gangway has been evaluated for fatigue performance using the ship loads and reaction loads
Fatigue Proposed Modifications

Modifications developed to extend the predicted fatigue life

Models developed to predict fatigue life are also used to develop and verify design modifications
Special studies

- Corrosion Optimization
- Forensic Analysis
- Blast Wall Design and Analysis
- Hull Deflections for Topside Design and Assessment
- Thermal Stress Assessment
Corrosion Assessment – Feature Overview

SAGA is used by Viking team members to apply corrosion instructions that have been entered into a database system developed by Viking to manage corrosion gaugings:

- Location of gauging including tank and coordinates
- Gauged thickness
- As built thickness
- Calculation of corrosion rates for structure groups
- Implementation of future anticipated corrosion
- Class required steel renewal calculation

*Steel renewal at conversion given vessel design life*
SAGA applies the corrosion values by subtracting the FEA model scantlings:

- Plate thickness
- Beam and Bar Element Stiffener web thickness
- Beam and Bar Element Stiffener flange thickness

The model’s gauging database is compared and a corroded model is made:

- As built model and database thicknesses are compared and validity checked
- Plate thickness and stiffener properties are updated
- Interpolation options for elements away from gaugings
- Percentage rule minimum corrosion can be applied
- Diminution corrosion can be subtracted

Resulting FEA Model with as gauged thickness
Forensic Analysis: Fracture & Fatigue Cracks

SAGA fracture mechanics is used on projects where a standard SN Curve approach is not considered sufficient, such as to estimate time for a crack to grow to a certain size or to become critical. Based upon Paris’ Law, our approach allows for the evaluation of crack growth of external and internal crack types typically found in ship structures.

The loading driving the fatigue stress ranges are defined by a Weibull distribution of a stress range calculated by loading and solving an FEA model. The model program allows us to investigate the effect of:

- Initial crack length
- Material strength
- Residual stress in the structure
- Compressive stress retardation accounted for
- Crack retardation models such as Wheeler
- Shape geometry effects in case of a damaged area

SAGA calculates a fracture damage ratio where amount of cycles in a design event is presented as a ratio of amount of cycles to failure.

Damaged areas experiencing cracks can be assessed for safety in operation.
Accommodation House Blast Study: Design and Analysis

- Determining the extent of possible damage to the accommodation house front by the ignition of a gas cloud on the upper deck of the FPSO

- Analysis also used to design appropriate blast walls to shield life saving equipment

Global deformed stress view
Hull Deflections for Topside Design and Assessment

- Initial deflections developed with constant radius bending theory
- Deflections in way of topside stool supports validated and confirmed with the finite element analysis
- Iterative analysis approach developed by Viking to study the effect of sliding connections between topside modules and topside support stools

Resulting Deflection in way of Topside Module
Thermal Strength Assessment for FPSO: Analysis Report
Environment specific for West Africa

Purpose of thermal analysis is to provide a detailed description of the calculation of bending stresses associated with thermal loading and any effect on the current Stillwater bending moment allowables on the FPSO.

- Increase in hogging and sagging stresses when considering the stress due to the thermal expansion coefficient of steel in way of cargo block frames where the cargo tank, off-spec tanks and slop tanks receive cargo at elevated temperatures as compared to the ambient temperature

- Calculation of allowable bending moment with the influence of thermal stresses
Related Professional Reports, Presentations and Industry Editorial

- **Structural Stress Analysis: Tested vs Predicted**
  *Maritime Reporter & Engineering News*

- **Structural Life Extension Study: FEA Based Corrosion Processing and Structural Optimization to Minimize Steel Renewal** *(Global FPSO Forum)*

- **Structural Design and Analysis of FPSO Topside Module Supports** *(Society of Naval Architects and Marine Engineers (SNAME))*

- **Structural Analysis and Modifications – 2 Tankers for Offshore FPSO and FSO Service** *(PRADS – Marine Science and Technology)*

- **Seakeeping Assessment of Large Trimaran for Naval Aircraft Operations** *(American Society of Naval Engineers – ASNE)*

- **Motions and Structural Load Predictions Using Wasim** *(DNV Software Magazine)*
Contact Information

Lars Henriksen | President
Lars.henriksen@viking-systems.net

Bo Williams | Director of Engineering
Bo.williams@viking-systems.net

Fritz Waldorf | Director of Sales and Marketing
Fritz.waldorf@viking-systems.net