Viking Systems International, Inc
Company Profile

Innovative Solutions for Ships and Offshore Structures
Viking Systems International was founded in 2000 by Lars Henriksen to serve the offshore oil and gas industry, the military and naval vessel community, and commercial ship owners and operators. Our experience, coupled with consistent application and development of innovative computer programs to serve our clients’ needs, propels our engineering teams to make sound and consistent decisions about our clients’ ship and offshore assets based on classical design rules as well as advanced tools for structural modeling, loading and assessment.

Our name ‘Viking Systems’ emphasizes that we design strong, quality ships, work in versatile teams with strong leadership and mentorship, and embody a healthy dose of exploration and innovation to form new ideas and opportunities – factors essential to our continued learning and success in solving our clients’ problems.

Viking is privileged to work with clients from diverse industries ranging from offshore structures such as FPSOs, FSOs, jack-up rigs, military vessels of all types including conventional, high-speed and coastal patrol vessels, as well as commercial ships ranging from offshore barges, heated cargo barges, tankers, containerships, to cruise ships.

Viking’s team is comprised of experienced mechanical engineers, naval architects, marine engineers, civil engineers, software developers and business professionals.

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Arrangement and Surveys
Viking Systems assists its clients with structural layout design to accommodate the equipment and utilities required to be located and housed within the structures we design. Examples of structures that require good planning in advance are external turrets on FPSO’s where a number of pieces of equipment such as pipe racks, HPU’s, winches, and stores are required to fit within the limited space available.

Structural Design
For large and complicated structures, 3D modeling tools are used in understanding the structure concept to ensure it is properly designed. We use our FEMAP modeling tools as well as in-house software, SAGA, to allow the geometry model to be exported to AutoCAD for creation of 2D drawings and detailing.

Stability Assessment
Some of the stability analysis that Viking performs on all types of vessels: Intact trim and stability analysis, Damaged stability analysis, Freeboard calculations, Load line calculation, and inclining experiments.

Motions Analysis
Viking Systems provides motions and load prediction assessments on vessel designs to ensure that the vessel and its equipment can withstand the motions and loading when subjected to a defined set of requirements. The motions are calculated using advanced frequency domain and time domain hydrodynamic programs to simulate the response of a vessel in a number of wave environments to understand the performance.

Classification Rule Design
Viking uses rule assessment programs from the major classification societies, including: American Bureau of Shipping (ABS), Det Norske Veritas (DNV-GL), and Bureau Veritas (BV)

Hull Refurbishment
As ships and offshore structures age, corrosion, buckling, overstressing, accidents, and fatigue cracks may become an issue. Viking offers structural solutions to extend the life of the vessel. The below steps are performed by Viking’s team of engineers:

- Review of class records to identify past problems
- Identification of intended new service
- Structural Analysis
- Preparation of documentation
Finite Element Modeling
Through FEMAP and SAGA, Viking can rapidly and accurately create structural finite element models. Both global and local models are created with various model sizes and mesh density customized to meet the needs of the client and requirements of the particular project.

Dynamic Load Assessment
For ships and floating structures, the static and dynamic loads originate from pressures and acceleration occurring due to the static draft and dynamic motions of the vessel in a sea state. The dynamic loads are selected from statistical processing of hydrodynamic analysis results to maximize a range of load parameters such as global shear and bending, wave pressures, internal pressure, accelerations, and then applied to the finite element model.

FEA Strength Analysis
For ships and ship shape FPSO offshore structures, typically the structural solutions include deflections and stresses from the programs Nastran, LS-DYNA, and Sestra. The assessment of structural programs are done using SAGA to carry out advanced auto-preparation of assessment model to manage dimensions of members, yielding and buckling criteria and code checks, code checks per ABS, DNV, Lloyds, API, AISC, as well as rigorous stiffened beam and plate rules.

Spectral Fatigue Assessment
Viking has extensive knowledge and capability with fatigue of ships and offshore structures. Fatigue loading in ships and offshore structures involves an in-depth understanding of the day-to-day loads that occur throughout the life of the asset. Several parameters are included to properly assess the fatigue demand that can be expected considering both past damage built over time as well as the future damage: Wave scatter data, heading probabilities, loading case probabilities, and vessel draft probabilities.

Structural Optimization
Optimization begins at the start of the design effort. Naturally the structural models are used to determine the areas of the vessel that require reinforcement, whereas the areas that could be reduced in strength are often not reviewed in further detail. Viking has developed a design optimization procedure, as well as a SAGA feature, that allows for the optimization of a structure through an interactive software solution that can be used on all types of ships and all types of failure modes.
Mooring and Riser Structures
Viking’s teams of engineers are skilled in FPSO External Turrets, FPSO Internal Turrets, FPSO Spread Mooring, FPSO Riser Porches, Local Riser Foundations.

Topside Stools
Viking pioneered technology to assess the combined loading of the topside modules onto the hull through the stools, and from the vessel bending imparting loads onto the topsides through the stools. This work has led to the development of SAGA software features that allow us to assess the loads coming from the topsides and the hull side as well as the loads that are taken by the stools. Often the topside stools are designed in one of the following ways:

- Four-point supports with relatively large stools and flexible bearings
- Multipoint supports with flexible transverse gussets
- Multipoint supports with flexible elastomeric bearings
- Multipoint supports with sliding bearings

Viking has designed and analyzed the above types of module stools and their hull reinforcements using technology that captures the effects of the rigid, flexible, or sliding connection type. This ensures the strength and fatigue performance of the stools under environmental loading and operational on and offloading loads. Often a deck sub model with modules and stools and their connecting types is used to determine reactions and stress in critical members of the design.

Foundations and Jackup Structures
In addition to mooring, riser and topside support structures, Viking designs foundations for all types of shipboard utilities and equipment such as crane and helideck foundations, offloading reels and platforms, flare towers, blast walls, and pipe racks. On FPSO, FSO and Jackup Offshore installations, we primarily use design codes from ABS FPI Rules, ABS MODU Rules, BV Parts A-D and NI593, API RP 2A, DNV OS-C101, RP-C201, RP-C203, RP-C205, RP-C206. Jackup FEA model of a MOPU conversion used to check vibration modes, p-delta effects, wind, wave and current loads.
**Advanced Analysis**

*Forensic Analysis*
Viking works to help clients when a structural issue has occurred due to various incidences, such as:
- Collision with another vessel
- Accidental overloading
- Overstressing a design
- Excessive corrosion

*Vibration Studies*
Shown is a vibration analysis that Viking performed to determine the natural frequencies of a steel lighting support post to be mounted on the deck of an FSO vessel. The model is created through SAGA and Nastran modeling systems. The methods are both natural free vibrations and forced vibration analysis.

*Explosion Simulation*
Viking is engaged in the design of structures to withstand blast pressures from the risk of explosions onboard vessels. The pressure profiles are applied to the structure models of various components of a vessel design using a combination of several advanced procedures and software.
Collision Studies
Viking performs collision studies during the design of vessels as well as during forensic studies. The work includes the use of non-linear time-domain finite element analysis procedures where the striking vessel is modeled to provide the energy imparted onto the vessel of interest. The studies involve several analyses to determine:

- Side shell strength of the vessel capturing when structure fails and no longer is effective
- Penetration depth
- Possible breach of innerskin bulkheads
- Residual stress locked in the structure after impact
- Dented shape of the damaged area for further study

FPSO Hull Assessment
Viking provides FPSO structural design and analysis services on both conversion and new build projects and obtains classification society approval within our SAGA program. Typically sensitive to schedule and cost, Viking’s team has a long track record of delivering quality structural solutions under high-pressure schedule requirements. Common projects for oil and gas FPSO and FSO vessels are assessment and selection of suitable conversion candidate vessels, corrosion and crack condition assessment, strength and fatigue assessment, determination or structural solutions for service offshore, and creation of design drawing for use by shipyard during conversion.

Topsides Module Supports
Viking has worked on projects involving both four-point and multipoint support systems. In these projects, structural arrangement approach may be based on stools, support frames, gusset plating, as well as module pancake structure arrangements. Advanced technologies have been developed to be able to incorporate the effect of uplift and friction occurring from applying sliding connections to multiple stool arrangements (requires an iterative FEA solution) as well as flexible bearing connections which provides the ability to simulate the elastomer and steel properties in vertical and horizontal directions. Viking presented a paper at SNAME 2008 annual meeting in Houston, TX on this subject.
Mooring Support Structures
Viking has designed support structures for all types of mooring systems, typically chosen based on water depth and loads arising from mooring and riser loading on the vessels. In addition to spread-moored arrangement, Viking has designed and assessed turret types, such as:

- External Turret (rigid arm type, or full bow cut type)
- Internal Turret (typically located in a forward cargo tank)
- Aft end mooring systems (tower yoke system)

Installation of a turret onto the mating turret support structure:

Riser Support Structures
The team of engineers at Viking have designed and analyzed riser support structures on several FPSO vessels. These structures are added to the side of the FPSO and receive loading from both static and wave hull girder loading as well as static and dynamic loading from the risers themselves. Within SAGA, Viking has developed technology to manage:

- Hundreds of combinations of hull induced and riser induced stress combinations to be able to ensure that all strength design conditions are met
- Thousands of sea state induced fatigue stress ranges using Weibull and Rayleigh distributions

Defense and Military

Military and Navy Monohull Vessels
Viking has worked on practically all of the US Navy surface combatants and amphibians including DDG, CG, LHD, and LSD vessels during an effort to apply recent corrosion gaugings to the finite element models. This effort was undertaken by applying a highly advanced method in SAGA for consistent application of corrosion and update to finite element plate and beam properties to the areas that experience corrosion. Viking has also been responsible for the FEA based design verification of the Mobile Landed Platform vessels MLP-1, MLP-2, MLP-3. All classed by American Bureau of Shipping (ABS).
**Advanced Hull Forms**

The structure of advanced hull forms, such as catamarans and trimarans, is subject to loads that are not seen in conventional hull forms and require a unique blend of skills, including:

- **Hydrodynamics Analysis**
  - Model test data interpretation
  - Non-linear time-domain hydrodynamic analysis
  - Whipping analysis
  - Tracking and analyzing accelerations and hull forces and moments

- **Maximizing Load Parameters**
  - Vertical shear and bending (torsion)
  - Transverse shear and bending (squeezing)
  - Prying moments
  - Wet-dock immersion

- **Assessment of stiffened plate yielding and buckling**
- **Optimization of scantlings**

**High Speed Vessels**

High Speed vessels experience a unique blend of loads, and require the use of model test results and hydrodynamic analysis to understand the dominant load parameters:

- Whipping induced bending moments
- Slamming pressures
- Safe Operating Envelope defining allowed speed in headings
- Optimization of scantlings to ensure lightweight design

Viking’s experienced team of engineers applies high speed light craft design rules built into the SAGA program.

**Transportation Industry**

**Tanker, Container and Bulk**

Viking is a premier solutions provider of structural design, analysis, stability and motions analysis as well as classification services for container ships, tanker vessels, and bulk carriers.

**Cruise Ships**

Viking has worked on the design of cruise ships using classification society rules and advanced finite element tools developed specifically to handle the deck-to-deck loading through pillars and the design of door and window openings.
Barge Structural Design

Our team of experienced engineers performs structural design and classification calculations of double-skin cargo barges for ocean and river routes. The design work involves rule calculation according to classification society rules and delivery of complete structural drawing of the vessel to the shipyard. Viking has extensive experience with the design of heated cargo barges such as asphalt barges as well as vessels carrying phenol. We have also designed heating coils to maintain the temperature of the heated cargo as well as fuel systems.

Luxury Yachts

Viking provides some services in the luxury yacht industry, primarily with design of the engine foundations where often times the composite material requires reinforcement to minimize deflections in a way of the propulsion systems. This allows for smooth and quiet operation avoiding damage to the shaft bearings and the foundations.

Structural Naval Architecture

Features of SAGA allow Viking to reliably and rapidly model, load, balance, and evaluate FEA models against classification society structural codes from ABS, DNV, BV, Lloyds, API, AISC and other rules.

We have achieved a flexible structural modeling, loading and evaluation tool interacting and translating with other efficient industry-accepted modeling software (FEMAP, Ansys, SACS), FEA Solvers (Nastran, Sestra, LS-Dyna), Stability Programs (Hecsalv), and Hydrodynamic Programs (WADAM, Wasim, Aqwa, Wajak). The results are available in virtual reality modeling language (VRML) format that are viewable in web browsers. The SAGA computer program has been applied to ships and offshore structures fabricated from steel, aluminum, and composites construction materials, using our process of:

- Assessment against any number of rules and any number of load cases, with plots showing the maximum response for each structure under design loads
- Calculation of paint areas, weld lengths, weights, centers of gravity, etc
- Plotting of results into typical structure groups to easily understand the results and allowing easy access to the data needed to update structural drawings and create reports

For 3-D FEA Modeling SAGA is used to rapidly create ship finite element models via import of CAD transverse section offset data in formats used by surface modeling tools. The file formats supported include AutoCAD .dxf, GHS .gf1, and HECSALV .hul files.
**Loading Analysis, Balancing, and Interfaces to External Programs**

The grouping of finite elements is carried out by SAGA to support naval architecture loading groups throughout the vessel. The loading groups include the external hull, tanks, deck areas, engine room and other user defined groups depending on the analysis requirements. The hull group can be exported in Nastran format for loading by external programs such as WASIM, WADAM, LAMP, or by SAGA using built-in classification society rules.

**Evaluation of Results**

SAGA reads stresses from Nastran and from DNV’s Sestra program for assessment against the yielding and buckling requirement of classification societies ABS, BV, and DNV. SAGA performs advanced post-processing of results by establishment of structural failure regions in combination with material, property, deflection, and stress data from the finite element model. SAGA is capable of using classification society rules from ABS, DNV, BV, and Lloyds. Additional custom code-checks are easily programmable by the user via spreadsheet interface.

**Corrosion Assessment**

SAGA applies corrosion instructions that have been entered into a database system. This system is developed by Viking to manage the corrosion gaugings: Location of gauging including tank and coordinates, Gauged thickness, As built thickness, Protection of future anticipated corrosion, Renewal required class steel renewal calculation requirements. SAGA applies the corrosion values by subtracting the FEA model scantlings. 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 update
- 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:

**Fracture and Fatigue Cracks**

SAGA is used on fracture mechanics projects where a standard CN Curve approach is not considered appropriate. The fracture mechanics program is based on the Paris’ Law
approach described in SSC-409 and 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
- Residual stress in the structure
- Compressive stress
- Wheeler retardation model
- Shape geometry effects in case of a damaged area

Finite element model stress ranges are used in SAGA to calculate a fracture-damaged ratio where amount of cycles in a design event is presented as a ratio of amount of cycles to failure.

**Code Compliance Check**

SAGA used built-in design code checking from below regulatory bodies:

- ABS FPI Rules
- ABS MODU Rules
- ABS HSNC High Speed Naval Craft
- BV Parts A-D and NI593
- API RP 2A
- DNV OS-C101
- DNV RP-C201, RP-C203, RP-C205, RP-C206

**Results Presentation**

Viking Systems SAGA program prepares results for our users and clients using a Virtual Reality Modeling Language (VRML) format viewable in standard web browsers and other programs the read VRML, for example Rhino. The result files area available for use by information technology interested clients wishing to see the results in interactive 3D rather than simply as shown in reports.