RELIABLE APPROACH FOR TRANSPORTATION FATIGUE ASSESSMENT OF FIXED PLATFORM TOPSIDES USING FULLY INTEGRATED MODEL BASED ON SPECTRAL FATIGUE ANALYSIS

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This paper presents transportation fatigue assessment using fully integrated model for fixed platform topsides and transportation temporary structures; loadout support frame, seafastening and grillages. In assessing fatigue strength for transportation, one would generally ignore flexibility of vessel or, consider only global longitudinal deflections using stick-framed model. However, fatigue is very local failure phenomena arising from repetitive cyclic loads and besides, since topsides and temporary structures are directly connected to flexible vessel, the local hotspots would be sensitively responded from the vessel motion and deformation. Thus, the fatigue assessment method which is currently in general use should be reconsidered in terms of accurateness and reliability. On the contrary, the fatigue assessment using fully integrated model comprised of topsides, loadout support frame, grillage and skidway can give more reliable and accurate fatigue life than the generally used method. Besides, with this fully integrated model it is not necessary to separately run FE analysis to calculate stress concentration factor considering exactness of load paths, boundaries and integrated stiffness. Using this approach, the spectral fatigue analysis for fixed platform topsides of 17,000MTon which is transported by heavy transportation vessel (HTV) from fabrication yard in South East to North Sea was applied.
For this, SESAM package was utilized from FE model to fatigue damage calculation. Hydrodynamic analysis to compute wave pressure and inertia was performed by WADAM using fully integrated model and compared to motion RAOs provided by T&I Contractor to ensure the integrity of mass model. To sort out the most critical hotspot locations among numerous connections to be checked for fatigue, screening step was implemented followed by detail fatigue analysis using hotspot fatigue model was done. This paper covers overall methodologies and the applications used to achieve credible fatigue results from fully integrated modeled analysis for topsides transportation.

Keywords: Spectral Fatigue Analysis; Integrated Analysis; Topsides; Transportation; Loadout Support Frame

1 Introduction

Topsides of offshore fixed platform should be transported using barge or heavy transportation vessel (HTV) to integrate with pre-installed jacket by means of lifting or floatover mating. Not only that, but onshore platform should be also transported in case that the field is far and remoted. In general, for short transportation duration shorter than 3 days, the fatigue analysis may not be necessary. But, long transportation through sea environment will affect structural endurance. Fatigue crack is sensitively local failure phenomenon depending on structural geometry, weld type, etc. Particularly, most of topsides are stick-framed structure and relatively less stiff than transportation vessel but is still flexible. Besides, transportation temporary structures such as loadout support frame, skidway, grillage & seafastening are directly connected to the vessel, for

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which their local connection may be influenced enough to initiate fatigue crack from hotspot-sized local deformation.

Nevertheless, many projects mostly tend to use independent stick-framed structures ignoring the local connectivity, flexibility of vessel or or, considering only global longitudinal deflections in performing fatigue analysis. With topsides models which are stick-framed using commercial program SACS, FPSO topsides have been mostly analyzed for fatigue analysis as well, which may be similar with topsides transportation on vessel or barge. It may be obvious that these approaches would be simpler and lead to conservative fatigue damages but is not clear in calculating fatigue life during transportation.

For this, topsides of 17,000MTon which is for redevelopment of North Sea field was considered. As per the design basis, the topside was designed for transportation from fabrication yard located at South East to the operation site in North Sea. It is fabricated on loadout support frame (LSF) sitting on skidways and then, skidded on to heavy transportation vessel (HTV) by strand jack system from quay side. Afterward, temporary structures like seafastening, grillage are installed for its safe journey. To transport the topsides, a self-propelled HTV vessel was assigned.

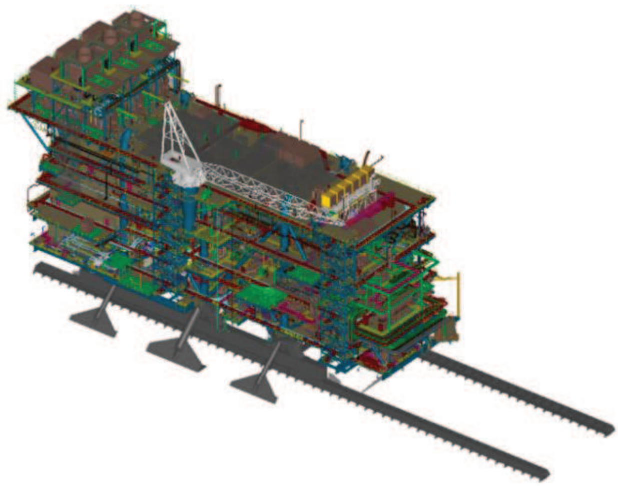

Figure 1. Platform along with Temporary Structures

For fatigue analysis, DNV SESAM package was utilized. Using GienE and PRESEL, finite element-based supermodels for topsides, transportation temporary structures and vessel were created and assembled to single integrated model. With the integrated model, hydrodynamic analysis was performed by WADAM to get as accurate deformations of vessel as possible, so that loads from wave pressure & inertia can be mapped to respective structures. To perform FE analysis for the integrated model, SESTRA was utilized and, with the stresses computed from FEA the fatigue damages were obtained through STOFAT by inputing necessary information like wave scatter diagram, S-N curves, hotspot extrapolation points, etc.

Two (2) steps were consecutively conducted to save runtime in running FE analysis in creating fatigue meshes and performing spectral fatigue analysis, which are screening analysis step to find out critical fatigue-prone locations among numerous similar connections and then, detail hotspot analysis step using thickness-sized meshes for the selected hotspots.

2 Procedure for Spectral Fatigue Analysis using Integrated Model

The SESAM integrated model for global structural analysis was used for the spectral fatigue analysis for TEG transportation TEMPS & connections of HTV. SESAM PRESEL is utilized for the integration from individual model such as topside, transportation temporary items and HTV. With the mass-tuned integrated model the hydrodynamic analysis is carried out using Hydro-D / WADAM and structural FE analysis using SESTRA. Finally, fatigue assessment for TEMPS & HTV connections is performed by STOFAT. Figure 2 presents the general procedure using the integrated model to obtain the detail fatigue damages for transportation TEMPS & HTV connections.

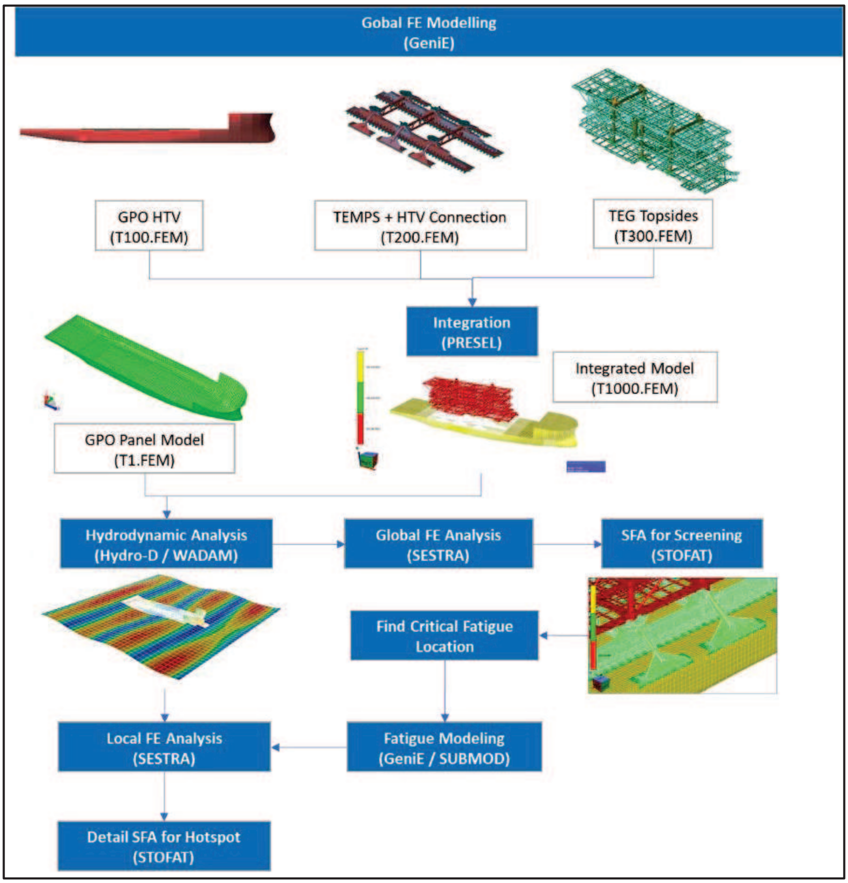

Figure 2. Procedure for SFA of Transportation TEMPS & Connections of HTV

3 Integration of Models

Before integrating to single model, every submodel, which is called 'Supermodel', was created in SESAM GeniE. The integrated model is comprised of topside, transportation temporary structures like loadout support frame, skidways, seafastening & grillage and HTV.

4 Hydrodynamic Analysis

To relevantly map the external wave pressures and inertia loads to the integrated model, hydrodynamic analysis was performed using SESAM Hydro-D / WADAM which is based on 3D potential theory in frequency domain.

5 Integrated Mass Models

In performing hydrodynamic analysis, accurate mass distribution is essential. To achieve accurateness of mass & GoG of fully integrated model, tunning mass for each supermodel were performed before integration.

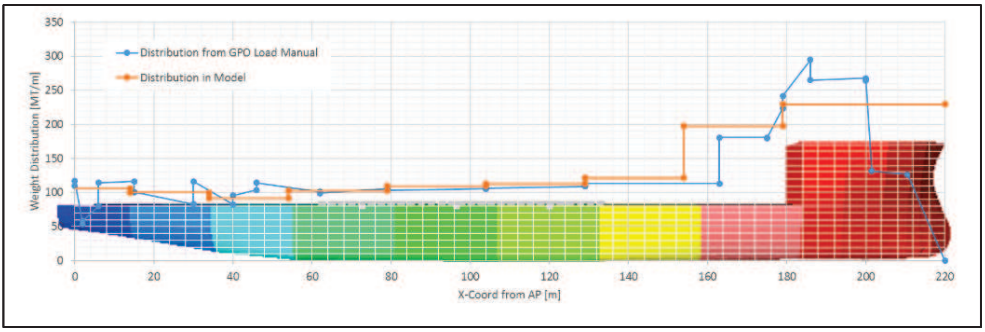

Figure 3. Modelled Weight Distribution & Comparison with HTV Load Manual

The fully integrated model assembled through SESAM PRESEL is presented in Figure 4. Note this integrated model was utilized in FE analysis using SESAM SESTRA as well.

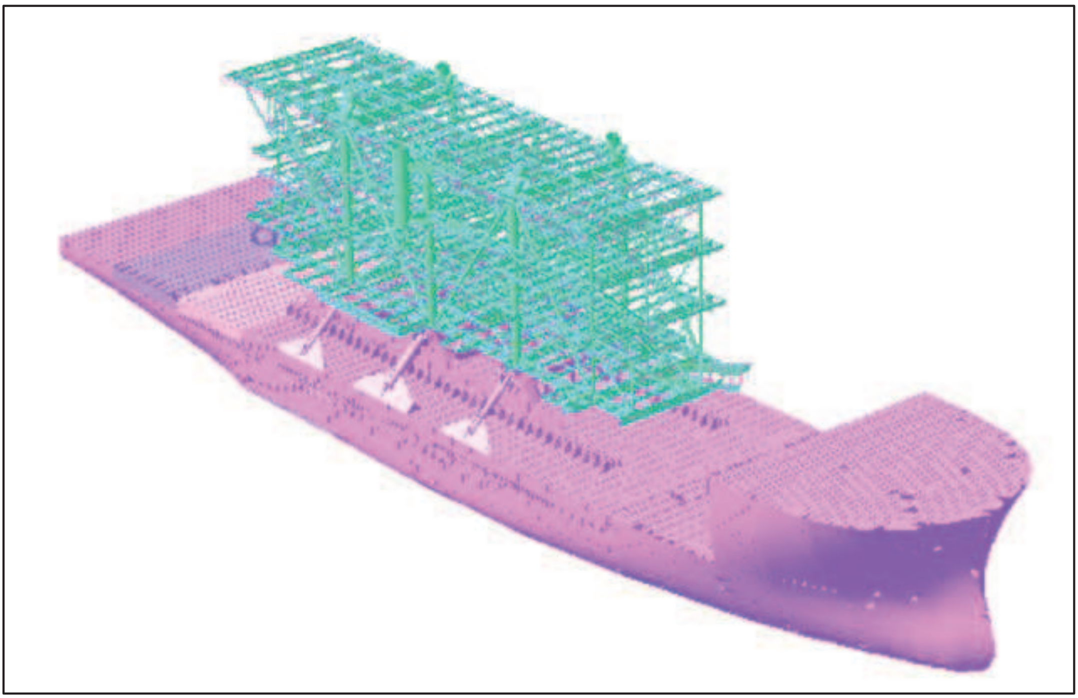

Figure 4. Integrated Model for Hydrodynamic & FE Analysis

6 Panel Model of HTV

To calculate the hydrodynamic loads and responses from potential theory, the panel model is to be generated. Panel model is single superelement and wet surface to be defined. The wave pressures computed from hydrodynamic analysis through WADAM will be mapped to structural FE elements defined as the wet surface.

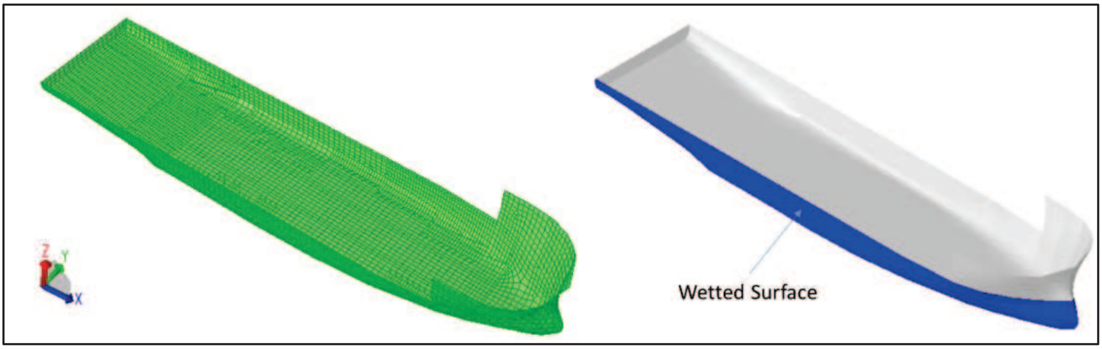

Figure 5. Panel Model & Wetted Surface for Hydrodynamic Analysis

7 Wave Direction and Period

In Hydrodynamic Analysis using the integrated model, eight (8) wave directions and forty (40) wave periods from 4 sec to 40 sec were applied in checking and calibrating motions.

8 Results from Hydrodynamic Analysis

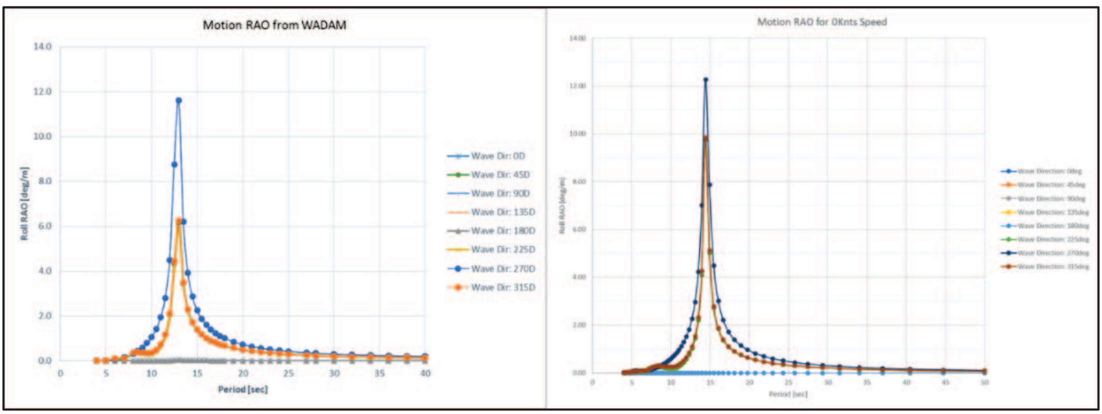

Figure 6. Roll Motion RAO from Hydrodynamic Analysis and Comparison

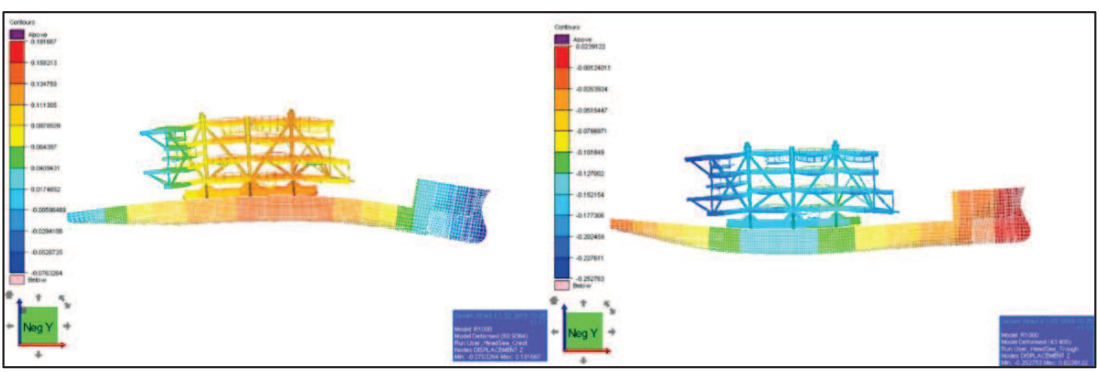

Figure 7. Results from Hydrodynamic Analysis (Hogging & Sagging Mode)

From the hydrodynamic analysis using WADAM which is frequency domain analysis tool based on 3D potential theory, the response variables, i.e., RAOs, for six (6) DOF motions are computed and compared with those provided by T&I Contractor to ensure the suitability of hydrodyanamic characteristics used in the analysis.

9 Spectral Fatigue Analysis

For the spectral fatigue analysis for TEG transportation temporary structures; LSF, grillage, sea-fastenings, skid beams and HTV connections, STOFAT of DNV SESAM package is used to calculate fatigue damage using 2D shell elements.

10 Wave Sea-states

T&I Contractor provided wave scatter diagrams (WSD) for respective voyage sectors that HTV will pass through, in which passing durations, heading angles and peaked parameters, γ, in JONSWAP spectrum were given for the transportation route. The duration in performing fatigue analysis was assumed 42 days including uncertainty.

From the combined wave scatter diagrams, central values of wave height & period based on fatigue central damage based on ISO 19902:2007 were calculated to figure out the most critical transportation month. Finally, the month of February was determined as critical transportation period.

11 Stress Concentration Factor

Geometrical stress concentration for the hotspot stress approach is calculated by SESAM STOFAT, in which the linear extrapolation to calculate hotspot stress was based on 0.4T and 1.0T from midline of shell element. Furthermore, 2nd order elements for FEA were utilized for calculating the hotspot stress from 2D shell finite elements.

12 S-N Curves

Basically, ISO S-N curves were utilized for the spectral fatigue analysis. For full penetration weld, 'D' curve was considered and, 'W1' curve for partial penetration weld, referring to DNVGL RP-C203. The thickness correction is also considered.

13 Screening Fatigue Analysis

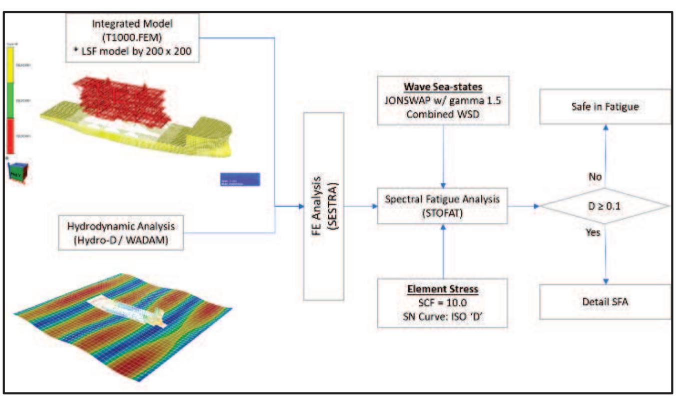

Figure 8. Procedure of Screening Fatigue Analysis

Since there are many hotspots to be checked for fatigue, the screening to find out most vulnerable locations for fatigue among geometrically similar connections is implemented. FE meshes of about 200 x 200 are generated and, total number of finite element is over 500K. In the screening phase, the element stress of specified finite element is extracted and multiplied by the assigned SCF of 10. STOFAT can execute the element fatigue assessment for the individual elements selected. In the element fatigue assessment, the fatigue points will be located at the element surface points. The procedure for the screening SFA is presented in below figure.

14 Detail Hotspot Fatigue Analysis

For the detail fatigue assessment based on SFA, the transportation TEMPS are categorized to five (5) submodels, which were determined based on the results from the screening SFA. Below figures shows the categorized sub-model for the detail SFA for the transportation TEMPS and hotspot fatigue meshes, i.e. t x t meshes, to calculate fatigue damage.

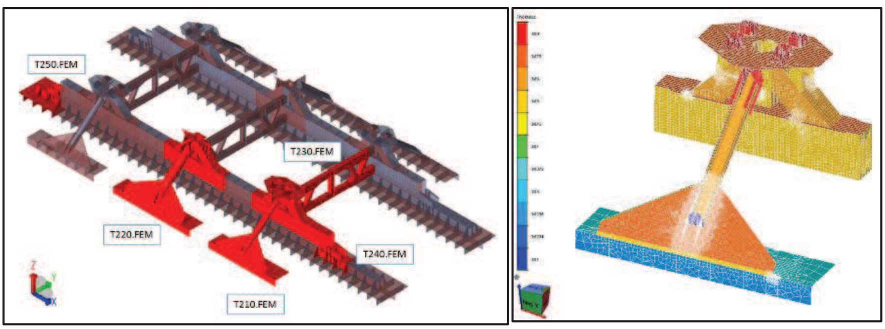

Figure 9. Categorized Submodels for Detail SFA of TEMPS

15 Results from Spectral Fatigue Analysis for TEMPS

Below Table summarized max. damages for respective submodels.

Table 1. Summary of Fatigue Damage from Detail SFA for TEMPs

Category	Submodel No.	Description	Max. Damage [-]
LSF & Sea-fastening	T210.FEM	LSF shoe, Roll brace & Hor. stringer at TEG Row- 1 / 3 and HTV Connection	0.228
	T220.FEM	LSF shoe, Roll brace & Hor. stringer at TEG Row- 2 and HTV Connection	0.186
LSF	T230.FEM	Hor. stringer	0.013
LSF & Stopper	T240.FEM	LSF, Surge/Pitch Stopper	0.632
Skidway	T250.FEM	Skid beams & HTV Connection	0.824

To validate fatigue damage of primary nodes of TEG topsides using fully integrated model, two (2) nodes were selected. Fatigue meshes for them were generated and combined with TEG topsides model by Multi Point Constraint elements in SESAM GeniE. Below figure shows FE models of two (2) nodes combined with TEG topsides.

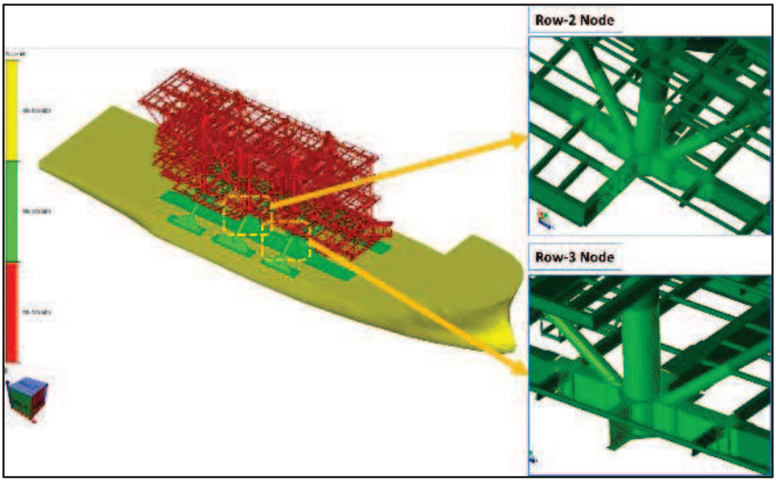

Figure 10. TEG Topsides and Submodels of Primary Nodes used for Fatigue Validation

The fatigue results calculated from the fully integrated model using SESAM STOFAT were compared with those from SACS fatigue analysis using individual stick-framed model. It was found that fatigue damages from the fully integrated model were slightly lower than those from SACS analysis.

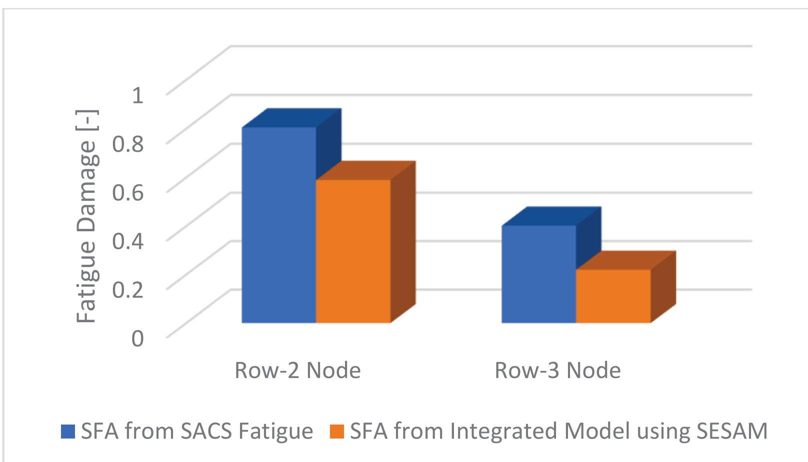

Figure 11. Comparison of Fatigue Damages from Each Method

16 Conclusion

Using the fully integrated model based on spectral fatigue analysis, fatigue damages for transportation temporary structures (TEMPS) like loadout support frame (LSF), grillages, skidbeams, and HTV's connections of fixed platform topsides can be calculated. The calculated fatigue damage includes the combined damage due to transportation inertia motions and hull deflections; is more accurate assessment for the transportation analysis.

References

"Fatigue Design of Offshore Steel Structures" DNVGL-RP-C203 (April 2016)
"Petroleum and natural gas industries – Specific Requirements for Offshore Structures. Part 1: Metocean design and operating considerations" DS/ISO 19901-1:2005