TRUNNION DESIGN OF TOPSIDES PLATFORM TO SERVE DUAL-PURPOSE OF LIFTING AID AND SUPPORT FOR FLARE TOP CHORD

CHOO FU HSIEN[1] and MILIND SALUNKE[2]

[1]*Mcdermott Asia Pacific, Menara Hap Seng 2, Jalan P. Ramlee, 50250 Kuala Lumpur, Malaysia*
E-mail: fchoo@mcdermott.com
[2]*Mcdermott Asia Pacific, Menara Hap Seng 2, Jalan P. Ramlee, 50250 Kuala Lumpur, Malaysia*
E-mail: msalunke@mcdermott.com

This paper briefed the design of Topsides Platform lifting trunnion to serve dual purpose of lifting aid and permanent support for flare top chord. The lifting of the 16,500 MT Topsides is performed by using trunnion. The trunnions are designed for the high grommet loads with Dynamic Amplification Factor. One of the four trunnions are provided with king post that will guide the installation of the Flare boom (130m length). After installation of the Flare boom, the top chord of the Flare boom is welded to the trunnion to act as a permanent support for the flare. Finite Element Analysis was performed to check the strength of the trunnion for lifting analysis, installation analysis of flare and flare in-place analysis.

The trunnion geometry was sized based on the installation requirements. Additional requirements from installation studies for flare installation was added on the trunnion. Extensive geometry checks were required to satisfy the clearances required from installation grommet, installation guide king post and flare connecting pup piece. 3D model was prepared to study the clearance required for sling installation, clear clash with Flare king post and welding tolerance for offshore welding of the flare pup-piece with the trunnion.

With proper geometry configuration of the trunnion it was able to perform the lifting analysis and later serve as support for the Flare boom. The proposed solution has been proven effective in terms of saving weight, space in layout and an efficient design to transfer the flare loads at strong nodal joint in the structure.

Keywords: Trunnion, Flare Boom, Lifting, Installation.

1 Introduction

Trunnions are extensively used for lifting of offshore structures as it offered superior structural strength when dealing with heavy structures. It is a norm that once the structure installation is completed, the trunnion will be left unused for the entire facility life unless for decommissioning purpose. This paper presents a dual-purpose trunnion which was designed for the lifting of Topsides and upon completion of lifting, served as a permanent support for post installed Flare boom top chord member.

The Topsides lift weight is 16,500 MT, with overall length and width of 100 m and 30 m respectively. It is supported by six tubular columns spaced at 2 x 23 m in the longitudinal direction and 24 m in the transverse direction. 4 trunnions are constructed at the extreme ends of

Proceedings of the 17th International Symposium on Tubular Structures.
Editors: X.D. Qian and Y.S. Choo

Published by Research Publishing, Singapore.
ISBN: 978-981-11-0745-0; doi:10.3850/978-981-11-0745-0_143-cd

the top columns. There are four main decks on the Topsides with 10 m height between decks. Two bridges are to be supported on the lower deck (Level 1) with sliding connection.

The Flare boom is a triangular lattice structure with single tubular top chord and double tubular bottom chord and weighs 625 MT. The Flare is extended out with a 60º inclination on the top chord, with respect to horizontal including a flare tip and an access platform at the top. The Flare boom top chord is supported on the North East trunnion above Level 4 while the bottom chord is supported on Level 3. Figure 1 presented the overall Topsides configuration together with the Flare boom.

1.1 *Topside installation method*

The Topsides will be lifted using a Semi-Submersible Crane Vessel (SSCV) in tandem mode using dual cranes. The lift arrangement is presented in Figure 2. Two pairs of grommet are arranged in the transverse direction of the trunnions to each hook.

1.2 *Flare boom installation method*

The Flare boom will be lifted using single hook during loadout and upended to inclined position in offshore using dual hook operation. The top chord will be temporarily hung onto the dual-purpose trunnion king post, with the bottom chord legs free to slide vertically. Pup piece is then field welded to fill the gap between top chord and trunnion, while the bottom chord is being welded to Level 3 of the Topsides.

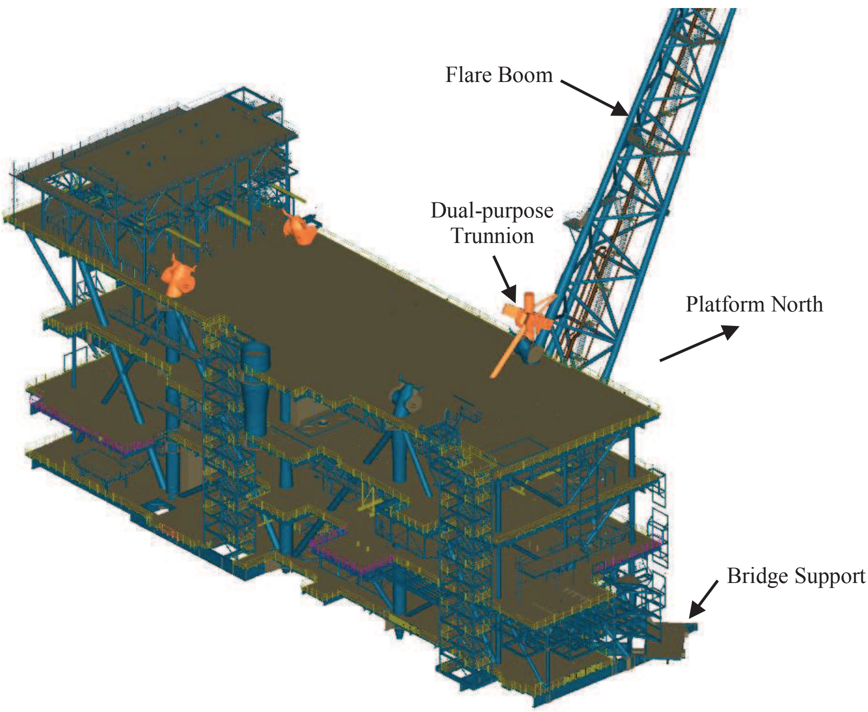

Figure 1. Overall Topsides configuration (Equipment not shown for clarity).

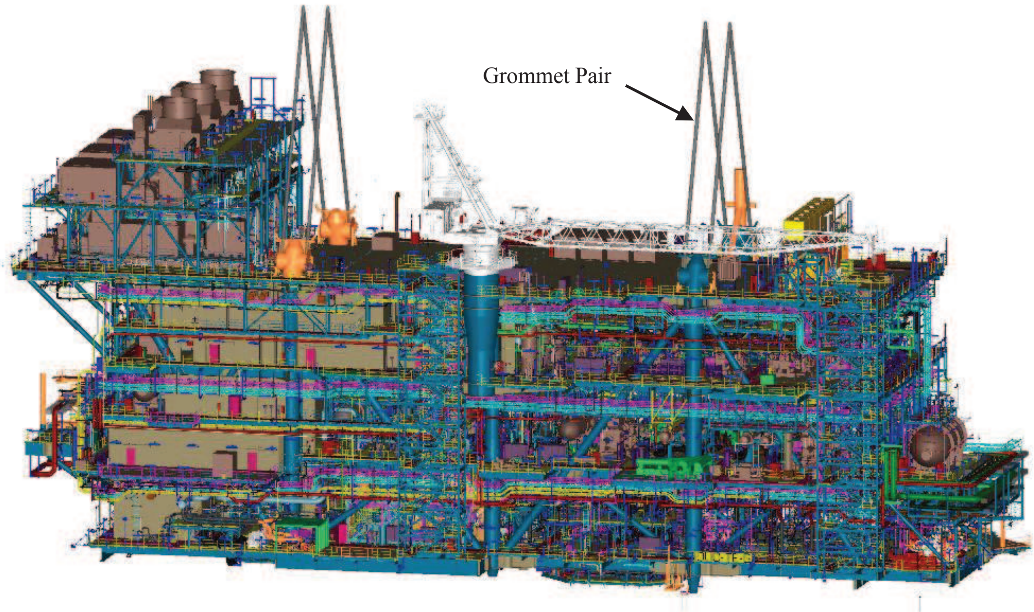

Figure 2. Topsides lifting arrangement.

2 Rationale for Selection of Dual-Purpose Trunnion

The key reasons that prompted the Flare boom to be installed on the trunnion are:

- During Front End Engineering Design (FEED), the Flare boom was supported on the eastern side of the Topsides, away from the major support grids, with the top chord connected to deck framing at Level 3 and bottom chord on Level 2. As the design progressed to Detailed Engineering phase, there was a need to extend the flare length due to heat radiation studies.
- The Topsides lift weight is approaching the lifting capacity of the SSCV and weight saving initiative needs to be adopted in the design to optimize the lift weight.

Considering the above concerns, the Flare boom was relocated towards west and the support was raised up by one deck level. This is the location of the major gridline where the Topsides column and trunnion resides. This is an ideal location that offered the following advantages:

- By raising the Flare support vertically up by 10 m (height between deck) while maintaining the same inclination angle and length, the heat radiation can be avoided, meeting the Safety requirement. There will be cost saving for the Flare compared to Flare extension at existing location.
- The existing location of Flare boom is not located on strong structural framing thus heavy deck reinforcement was required. By re-locating the top chord onto the deck column, it provided a strong support to resist the axial and bending moment from the Flare top chord. Deck reinforcement for the original deck strengthening for top chord can be reduced.

Based on the above cost and weight benefits, the dual-purpose trunnion concept was selected.

3 Trunnion Configuration

The dual-purpose trunnion main tube is built from tubular diameter of 2200 mm x 95 mm, with two trunnion stubs attached to the side of the main tube. The trunnion stub (diameter of 2000 mm x 75 mm), connected perpendicular to the main tube, is where the grommet is attached. A

90 mm thick main plate is slotted through both the trunnion tube and stub to enable the grommet load to be transferred to the entire trunnion tube. As the rest of the trunnion is hollow internally, additional diaphragm plate, stiffeners and ring plate were installed in the main tube as reinforcement. Refer to Figure 3. These components were strategically placed to ease welder access inside the tubular. The work point between the trunnion main tube and Topsides column is placed coincident with the center of the deck framing plate girders. This configuration reduces the eccentricity from the grommet axial line of action thus reduces the bending moment in the trunnion tube.

King post with diameter of 1350 mm x 75 mm thick is installed directly above trunnion main tube as installation aid for Flare temporary support. Flare hook pin which is connected to the Flare top chord will be rested on the king post, transferring entire Flare lift weight onto the trunnion while the pup piece and bottom chord is being welded. The trunnion and Flare installation aid is presented in Figure 4. All material used for the trunnion and its internal reinforcement is of grade 380 N/mm^2.

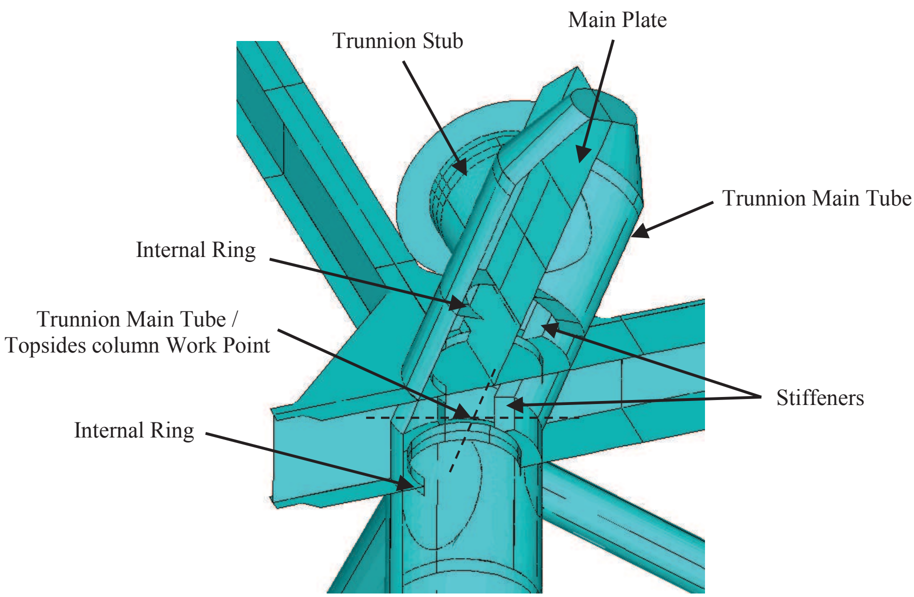

Figure 3. Internal trunnion reinforcement (King post not shown for clarity).

4 Trunnion Geometry Check

Geometry check using 3D model has been performed to ensure installation clearance, grommet clearance and fit up clearance of Flare hook pin is adhered to. This included the study for the weld access for the post installed Flare pup piece. All these were collaborated with the Offshore Installation Contractor (OIC) and adjustment were made to accommodate the clearances.

The top segment of the trunnion main tube was modified to be conical shape to allow for more grommet clearance to the trunnion when the Center of Gravity envelope shifts to extreme end of envelope. Adjustment were also made to the Flare boom vertical braces to allow for more access to weld the pup piece offshore.

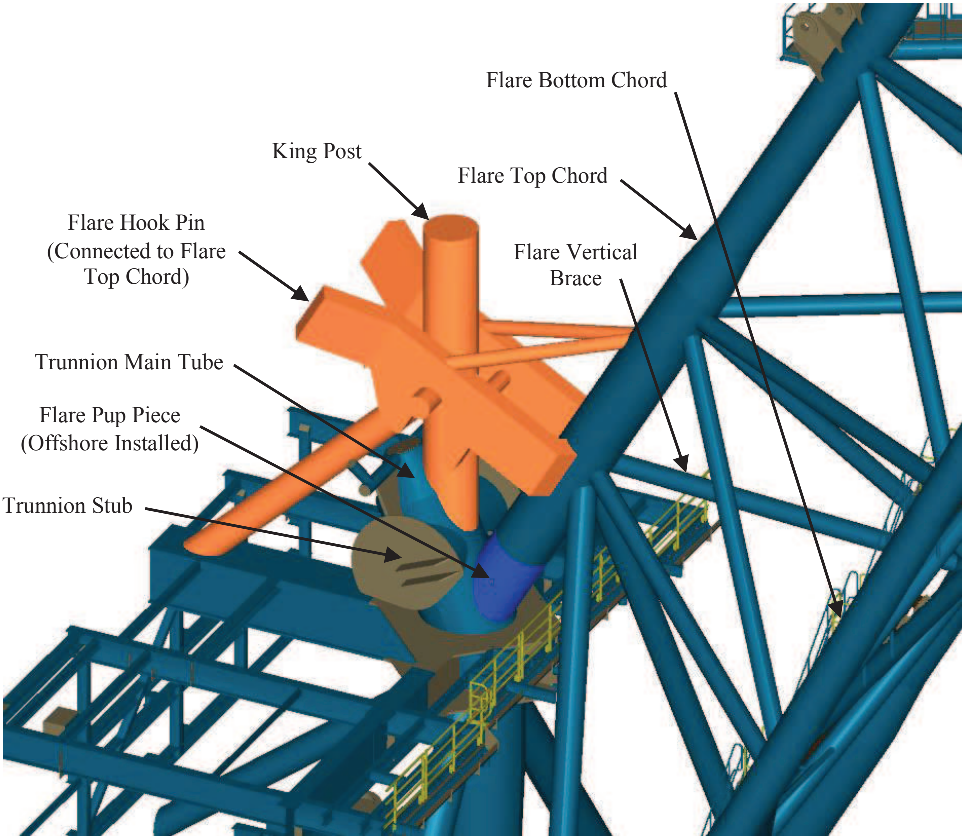

Figure 4. Component of dual-purpose trunnion with Flare installation aid.

5 Design Loads and Analysis

The dual-purpose trunnion is designed for three phases of loading, i.e. dynamic forces during lifting, temporary support loads from Flare during installation and permanent in-place load after Flare chords are fully welded. The analysis is performed using Finite Element Analysis (FEA).

5.1 *Topsides lifting analysis*

Lifting analysis was performed for factored weight of 17,500 MT in which additional margin of 1,000 MT was included. Sling/grommet force obtained from SACS software global Topsides lifting analysis was applied onto the trunnion stub. Working Stress Design (WSD) code was applied for the code check of the trunnion in accordance with the Offshore Installation Contractor requirement.
The following design criteria were considered:

- Dynamic factor of 1.62 has been considered for the sling force which accounted the Dynamic Amplification Factor (DAF), tilt factor, yaw factor, skew load factor and yaw factor.
- 60% - 40% sling force distribution was applied at each trunnion stub to simulate friction effect between grommet and trunnion stub.
- Out of plane force equal to 5% of sling force was applied at trunnion stub.
- Torsional moment about the axis of trunnion stub has been considered due to friction effect of grommet wrapped around the stub.

- Three variation of grommet angles have been considered, namely 60°, 67.5° and 75°.

Localized peak Von Mises stress was observed for the trunnion on areas with geometric change. Peak stresses were justified using DNVGL-OS-C102 for WSD design, with allowable stress of 1.18 x 380 N/mm^2 = 448.4 N/mm^2. The mesh size used was 100 mm x 100 mm. It is concluded that the trunnion is fit for Topsides lifting purpose.

Critical stress plot for the trunnion during Topsides lifting is presented in Figure 5.

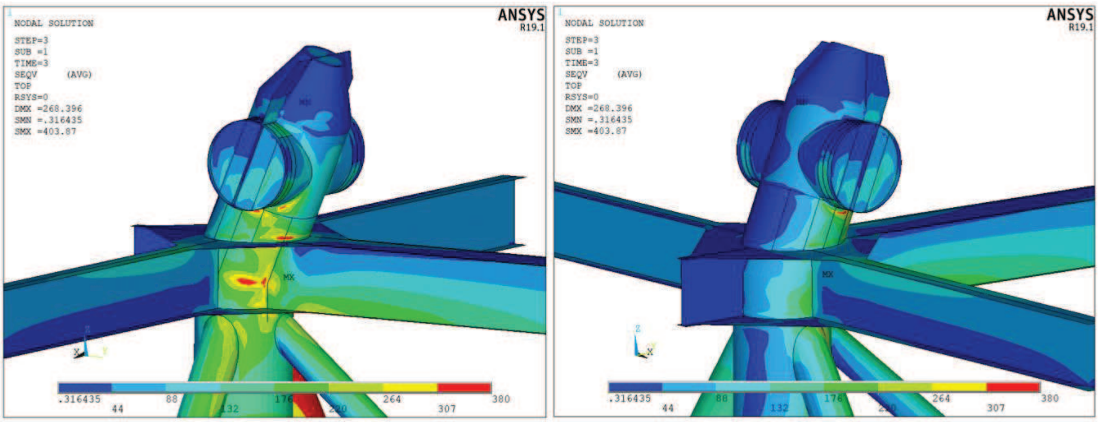

Figure 5. Critical Von Mises stress plot for trunnion lifting analysis (Grommet angle 75°).

5.2 *Flare boom temporary support analysis*

The entire king post and trunnion is evaluated for the full weight of Flare boom supported onto the king post. This simulation requires sub-modelling from global analysis. SACS software global model is used to obtain the joint displacement at sub-model boundaries. These displacement values are then applied into FEA model as specified displacement boundary condition. Load and Resistance Factor Design (LRFD) code was utilized for this analysis as required by Client.

The following design criteria were considered:

- Dead load of Flare boom.
- 1-year operating wind load of 19.5 m/s at 10 m reference height.
- 8 directions of wind heading (45° interval) considered on the Flare boom.

The yield stress for the material is 380 N/mm^2 while the allowable stress is 1.7 x 380 = 646 N/mm^2 based on DNVGL-OS-C102 for LRFD design, with 50 mm x 50 mm mesh size. Based on the Von Mises stress contour plot for the FEA, the maximum stress is 630 N/mm^2. It is concluded that the king post and trunnion has sufficient integrity to resist Flare boom dead and wind load during installation.

Critical stress plot for the trunnion during temporary Flare support is presented in Figure 6.

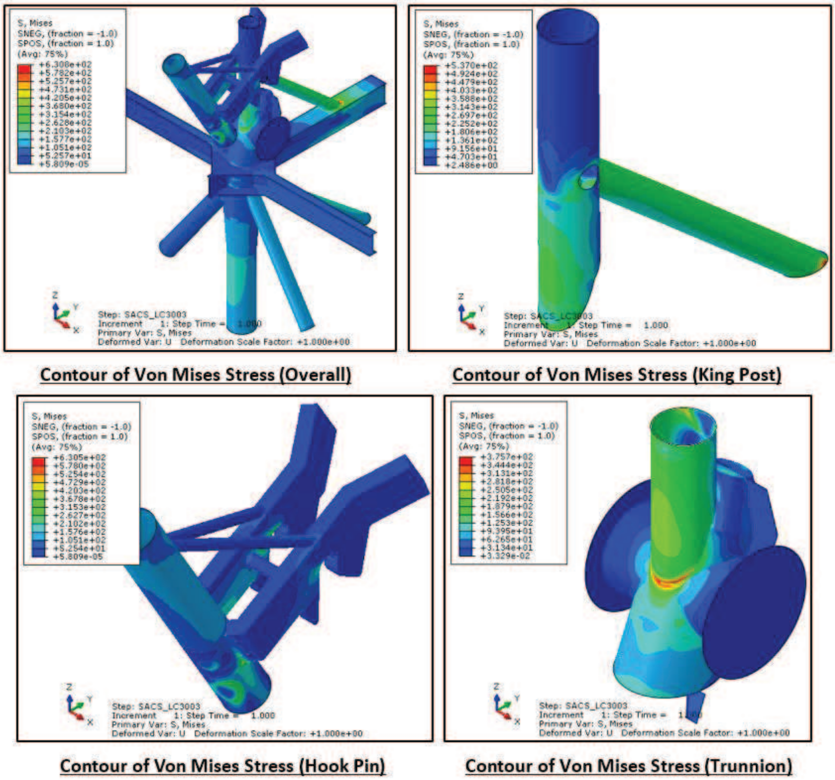

Figure 6. Critical Von Mises stress plot for Flare boom temporary support analysis (Wind from Platform East direction).

5.3 *Flare boom in-place analysis*

In-place analysis was performed using SACS software with the Flare boom chords fully connected to the Topsides. All the Flare boom and Topsides members were checked with LRFD Eurocode 3 as per Client requirement.
The following design criteria were considered:

- Dead load of Flare boom and Topsides.
- Operational load of Flare boom and Topsides.
- 1-year operating wind load of 19.5 m/s at 10 m reference height for Ultimate Limit State (ULS) design.
- 100-year operating wind load of 29.6 m/s at 10 m reference height for Ultimate Limit State (ULS) design.
- 10,000-year operating wind load of 37.2 m/s at 10 m reference height for Accidental Limit State (ALS) design.
- 8 directions of wind heading (45° interval) considered on the Flare boom and Topsides.

All the structural members satisfied the LRFD Eurocode 3 check requirements. The unity check plot is presented in Figure 7.

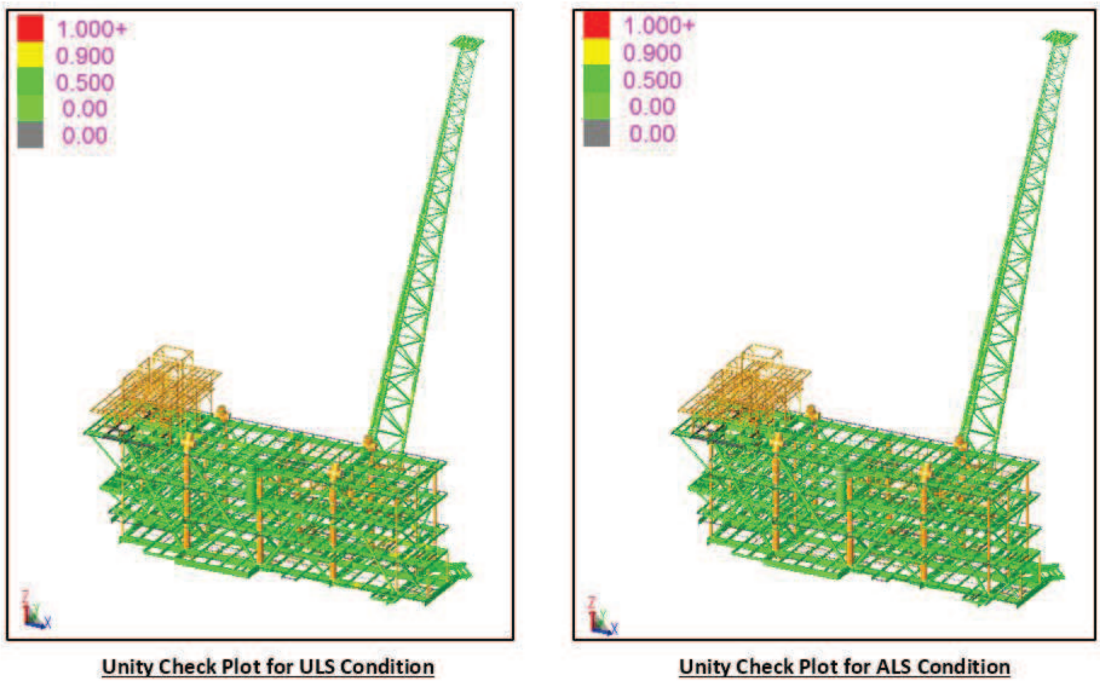

Figure 7. Unity check plot for Flare Boom and Topsides under ULS and ALS condition.

6 Conclusion

The concept of dual-purpose trunnion solution has been proven effective in terms of weight saving, space saving in layout and an efficient design to transfer the Flare boom loads to strong nodal joint in the structure. Early engagement with OIC in the early phase of project is essential to ensure feasibility and constructability of a dual-purpose trunnion.

References

American Institute of Steel Construction, Specification for Structural Steel Buildings, 7 July 2016.
DNVGL-OS-C102, Structural Design of Offshore Ships, July 2015.
Eurocode 3: Design of Steel Structures – Part 1-1: General Rules and Rules for Buildings, EN 1993-1-1, May 2005.
ISO-19902, Petroleum and Natural Gas Industries – Fixed Steel Offshore Structures, 2007.