The way to ECO-vessel: Reducing VOC from Hull Structural Aspects

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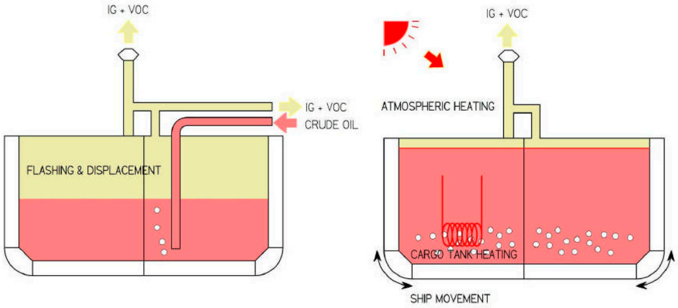
Abstract

Nowadays environment friendly product and operation is a big issue widespread in most of industrial field including ship building and operation. Regarding environment friendly operation of vessel, VOC reduction is very emerging. This paper introduces a case of the VOC reduction system and higher tank pressure application for shuttle tankers from the structural point of view. This paper covers structural arrangement, strength and fatigue assessment, relevant reinforcement, installation of the systems and tank test to confirm the structural integrity.

1. Introduction

VOC stands for Volatile Organic Compounds and is a mixture of light end components of hydrocarbons – methane, ethane, propane, butane, etc. NMVOC is the non-methane VOC consisting of ethane, propane, butane etc. NMVOC and NOX combines to ground level ozone which causes the detrimental effect on human health (eyes and lungs) and on vegetation.

In the ship operation, NMVOC occurs during cargo loading/unloading and voyage.



(a) Loading (b) Voyage

Fig. 1 VOC occurrence in ship operation

In order to control VOC emission, MARPOL requests crude oil tankers to have vapor emission control system and implement a VOC management plan. (MARPOL Annex VI Chapter III Reg. 16) And Norwegian authorities requests at least 78% of recovery efficiency of VOC in Norwegian territory. This is the trend of world business of eco friendly product and operation.

VOC control technology can be categorized as follows;

Table 1. VOC Prevention: Reducing the generation of VOC

	KVOC	VOCON	Increased Tank Pressure
Supplier	Knutsen OAS Shipping	SHI	Yard
Operation	Loading	Voyage	Voyage

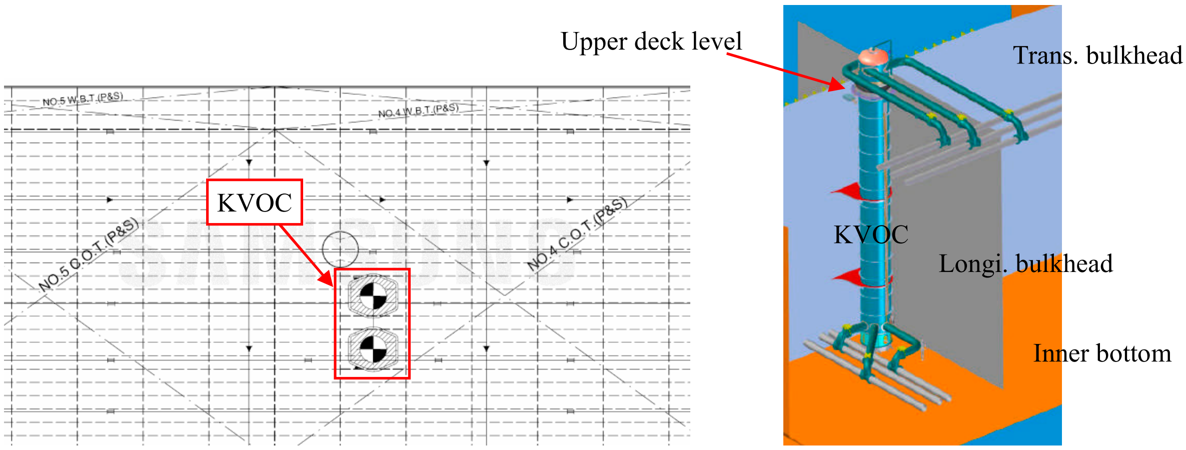
Table 2. VOC Recovery: Re-collecting the occurred VOC

	Re-liquefaction	Re-absorbtion		
Supplier	Hamworthy	APL	GBA Marine	Venturie
Operation	Loading, Voyage	Loading, Voyage	Voyage	Voyage

Samsung Heavy Industries developed a shuttle tanker of Aframax size with KVOC and higher tank pressure application to reduce VOC emission. This paper covers the structural design for the integration of KVOC and main hull structures and reinforcement of hull structures with higher tank pressure application.

2. Structural design for KVOC and hull integration

KVOC system itself was verified by its maker, Knutsen OAS Shipping and Shipyards carried out fatigue assessment for the interfaces between KVOC system and main hull structure. KVOC was installed on main deck of mid cargo hold area. Then critical points to be assessed are KVOC column penetration to main deck and connections between KVOC and hull structure which are directly affected by major hull girder loads.



(a) Upper deck plan (b) Iso-view

Fig. 2 Structural arrangement for KVOC

Following assessments were carried out by Shipyard;

1. Fatigue calculation for KVOC column penetration to main deck
2. Fatigue calculation for butt connection of KVOC insert and main deck

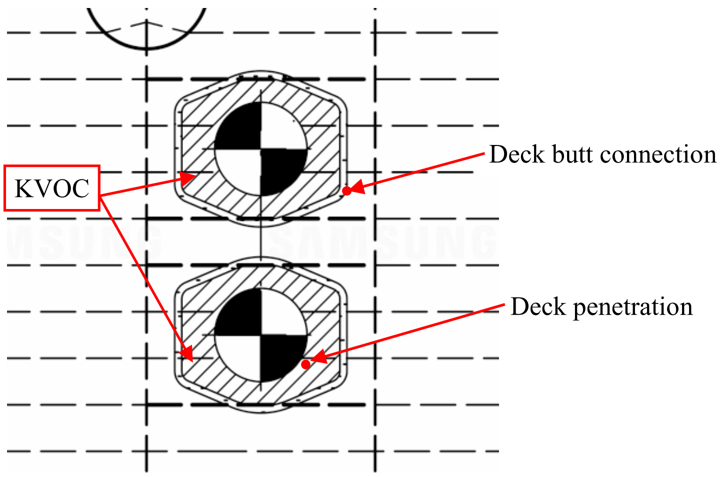
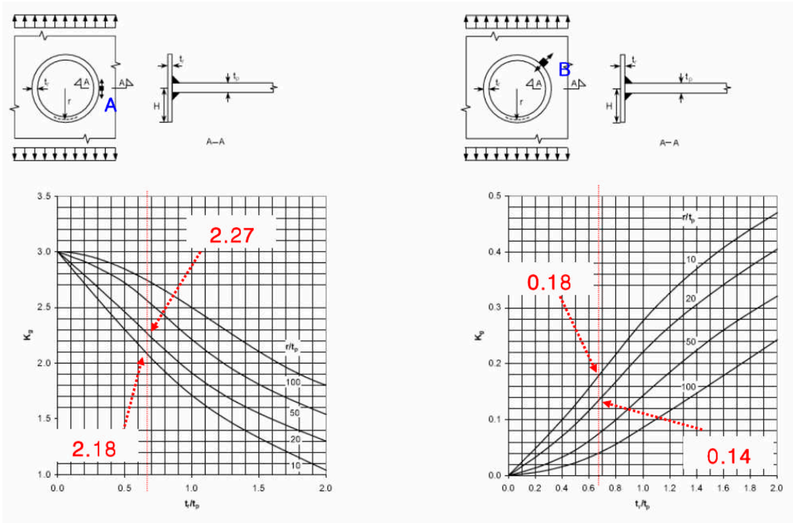


Fig. 3 Check points

Simplified fatigue assessment was performed through DNV CN30.7. K_g, stress concentration factors due to gross geometry of the detail for the deck penetration and butt connection were calculated as shown in Fig. 4 and 5. Dynamic stress range and cumulative damage ratio were calculated and relevant design improvement was achieved to satisfy with target fatigue life of 35 years under North Atlantic environment.



(a) K_g at hole with inserted tubular. Stress in plate, parallel with weld. ($H/t_r = 5$)

(b) K_g at hole with inserted tubular. Stress in plate, normal to weld. ($H/t_r = 5$)

Fig. 4 SCF for deck penetration

$$\mathrm{SCF} = 1 + \frac{6(\delta_m + \delta_t - \delta_0)}{t\left[1 + \frac{T^{1.5}}{t^{1.5}}\right]}$$

where

δ_m = maximum misalignment
δ_t = ½ (T− t) eccentricity due to change in thickness
δ_0 = 0.1 t is misalignment inherent in the S-N data for butt welds
T = thickness of thicker plate
t = thickness of thinner plate

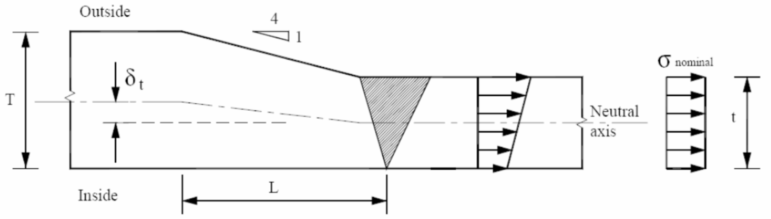


Fig. 5 SCF for butt connection with misalignment

Through this procedure, following improvements were applied to satisfy design fatigue life;

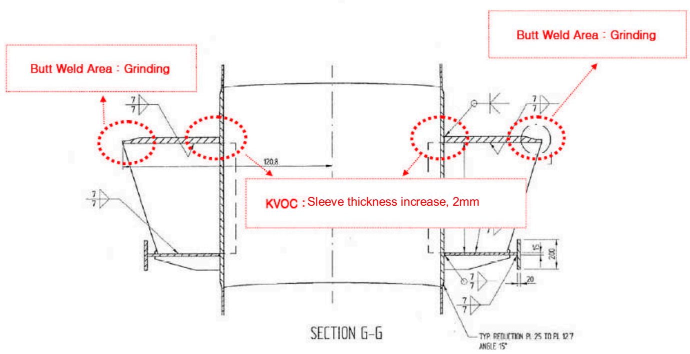


Fig. 6 Design improvement

3. Structural design for higher tank pressure

Resultant valve pressure was requested to be increased up to 0.7 bar. For the strength review of cargo tank boundary and its supporting structures, local scantlings for local and primary supporting members and 3D cargo hold analysis were updated considering additional tank pressures. And low cycle fatigue analysis was also updated according to DNV CN30.7 for the following locations;

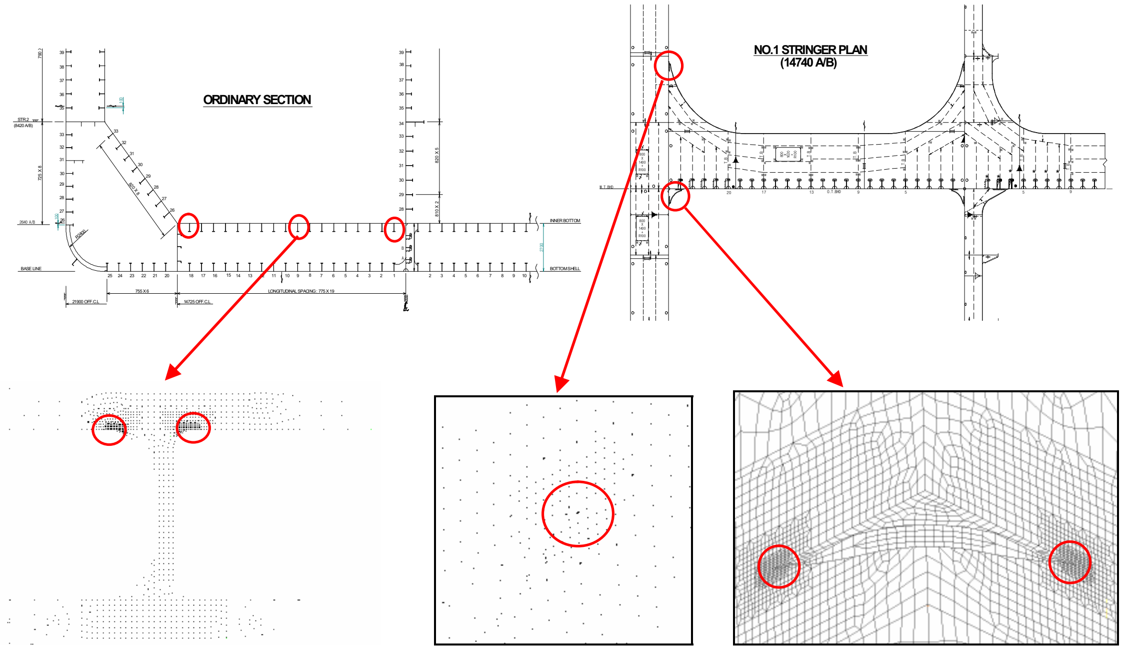


Fig. 7 Locations of low cycle fatigue analysis

Through these calculations, following improvement was added to conventional structural design.

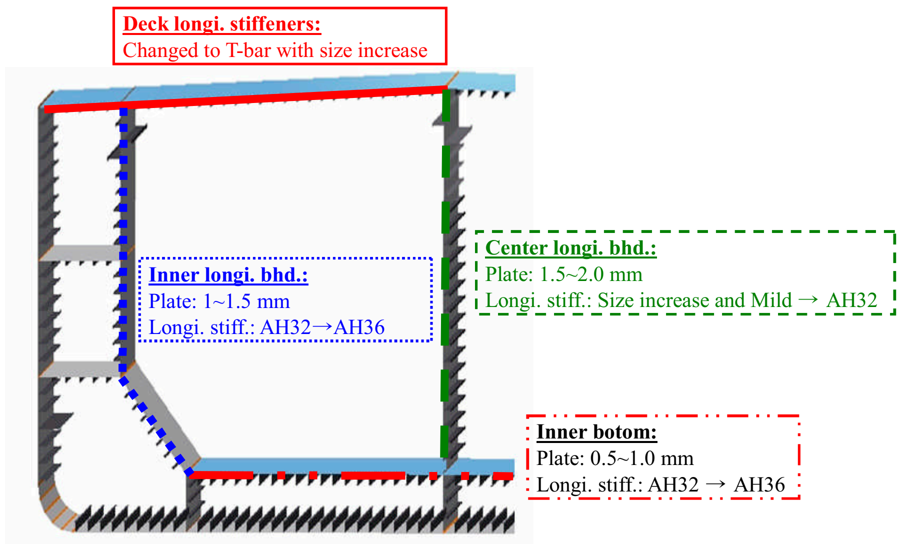
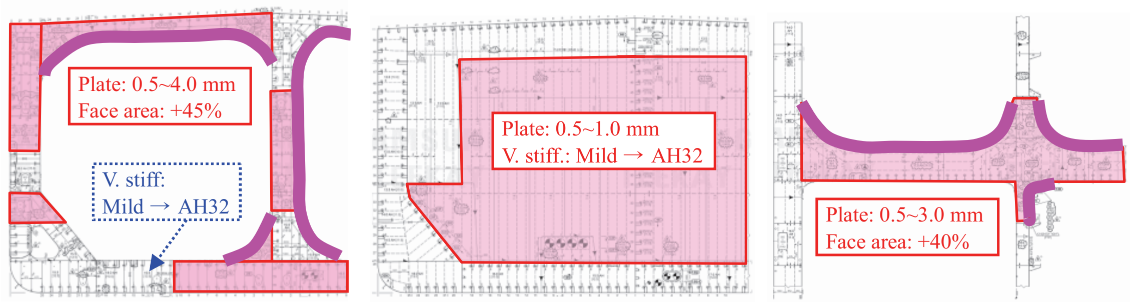


Fig. 8 Reinforcement for longitudinal members



(a) Typical webs (b) Transverse bulkead (c) Stringers

Fig. 9 Reinforcement for transverse member

4. Installation and tank tests

KVOC installation sequence is as follows;

Fig. 10 Installation sequence of KVOC

Hydro static test was performed to check the structural integrity of the tank boundaries and their supporting structural members with 0.7 bar hydro static pressure. A 7 m pipe was installed on main deck to make the water flood over the height of 7 m.

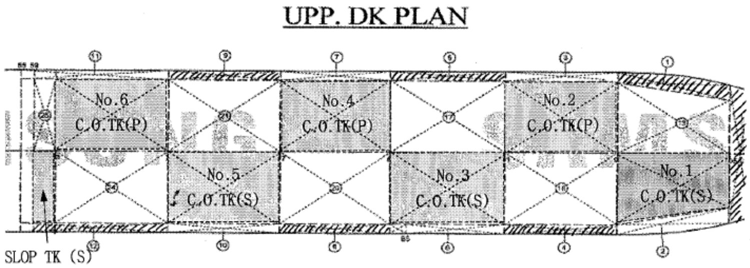


Fig. 11 Tank test plan

Fig. 12 Tank test

5. Conclusion

Samsung Heavy Industries developed a shuttle tanker of Aframax size with KVOC and higher tank pressures to reduce VOC emission. In order to verify the structural adequacy of relevant structural members, fatigue calculation was performed for KVOC and main hull integration. Local scantlings for local and primary supporting members and 3D cargo hold analysis were updated considering additional tank pressures. And low cycle fatigue analysis was updated. With appropriate reinforcement, scantlings and specific details were fully satisfied with Class and Buyer's requirement and their integrity was confirmed by tank test.

Samsung Heavy Industries are expanding this successful experience to more crude oil tankers and it would be a good example of eco-friendly vessel to comply with the needs of eco friendly operation worldwide.