NEW DESIGN
OF
SUEZMAX CLASS TANKER

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ABSTRACT

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The long-term operability and maintenance of ship structure is another great concern of Shipowners in line with the economical ship design. Accordingly, Hyundai Heavy Industries developed in 1999 new designs of tanker to satisfy these demands. As a typical case among several new designs the structural aspects of a Suezmax class tanker design is presented.

Robust hull structure is achieved by careful arrangement of limited amounts of higher tensile steel and by providing sufficient still water bending moment capability. The reliability of the structure is confirmed through extensive strength analyses and adoption of enhanced structural details. Special care is also paid to the arrangement of the structural members for easy close-up survey and maintenance.

For the subject new design, structural connections of the longitudinal stiffener are designed to meet with the requirements of minimum 30 year fatigue life according to the current calculation procedure set-up by the selected Classification Society. In addition, the fatigue strength of the structure is assessed rationally with an enhanced design S-N diagram (HD S-N Diagram), which incorporates the effects of re-distributed residual stress and mean stress induced by the static load. HD S-N diagram has been developed through numerous fatigue test results and is based on the hot spot stress for application to the evaluation of the fatigue strength of various weld joints with a unified S-N curve.

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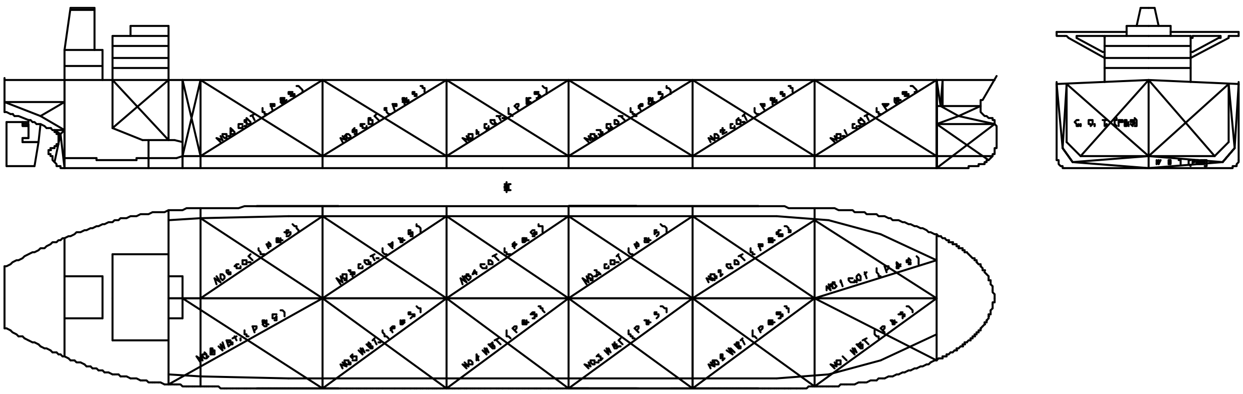
1.INTRODUCTION

The long-term operability and maintenance of ship structure is another great concern of Shipowners in line with the economical ship structural design. It has been, however, hard to fulfill the both aspects simultaneously, the long-term operability with the minimum maintenance of ship structures and the structural design with the economic shipbuilding cost. Hyundai Heavy Industries (HHI) developed in 1999 new designs for three(3) sizes of tanker (Aframax, Suezmax, and VLCC) to satisfy these Shipowners' demands, based on numerous shipbuilding experiences of double hull tankers. As a typical case among the three new designs, Suezmax class tanker design is introduced.

Fig.1 shows main particulars and schematic general arrangements of 165,000 DWT tanker, which was developed for HHI's typical design of a Suezmax class tanker. HHI's Suezmax class tanker has several main features such as the large deadweight and cargo volume, the optimized hull form and propeller, and the reliable hull structure requiring less maintenance. Among the several features, the structural aspect only is presented in this paper.



Length Overall	274	m
Breadth	50	m
Depth	23.1	m
Design Draught	16	m
Scantling Draught	17	m
DWT at Scantling Draught	164,600	MT
Cargo Tank Capacity	181,000	m^3
Main Engine	Hyundai – B&W 6S70 MC – C	
Service Speed	15.5 Knots with 15% sea margin	
Cruising Range	20,000	nm
Cargo Oil Pump	4,000 m^3/h X 3 sets	
Diesel Generator	730 kw X 3 sets	

Fig.1 General arrangement and main particulars of 165,000 DWT tanker

2. RELIABLE HULL STRUCTURE

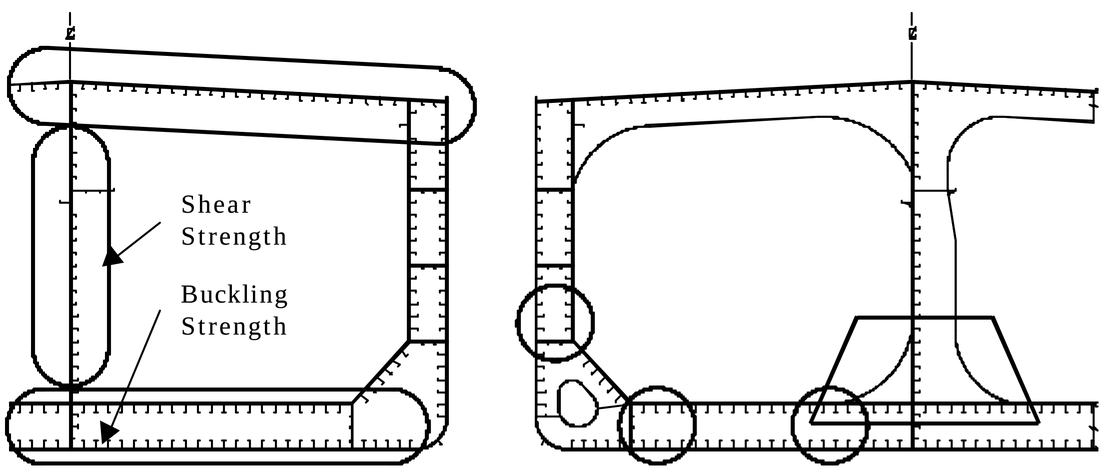
2.1 Frame Spacing

HHI's new design of a Suezmax class tanker adopts the wider transverse web frame spacing compared with the previous ones of last decades. The frame space of 4,850 mm in the new design is wider by about 17% than the one in the previous design in 1990s. The application of the wider frame spacing results in heavier scantlings of longitudinal stiffeners in accordance with rule requirements. Consequently it contributes to enhance the hull girder stiffness, while the local stress levels remain unchanged regardless of the frame spacing. Thicker plating by the wider frame spacing will present more corrosion redundancy considering that the percentage of remaining thickness after constant corrosion will be higher. Inspection and maintenance of hull structure also will be naturally easier due to the reduced number of structural elements and lesser welded joints/painted areas.

Economically, the design with the wider frame spacing causes the material cost increase. However, it has been verified that high productivity due to reduced number of structural elements and an efficient arrangement of structural members compensates the increased material cost. Accordingly, the adoption of the wider frame spacing has no effects on total shipbuilding cost. This has been able to be achieved by fully integrated and co-operative system between the design part and the production part.

2.2 Application of Higher Tensile Steel

An appropriate choice of structural material is very important for Shipowner from the viewpoint of an economic structural design as well as of avoiding undue maintenance costs. In consideration of the fatigue strength, the application of the higher tensile steel is rather limited with special attention.



(Except Bottom Plating)

Longitudinal members **Transverse web frames**

Fig.2 Areas where higher tensile steel of HT32 grade is used

(Except Bottom

Fig.2 shows the areas where the higher tensile steel of HT32 grade is applied. As for longitudinal structural members, deck plates and stiffeners, centerline bulkhead plates and stiffeners, inner bottom plates and stiffeners, and bottom stiffeners are constituted with the higher tensile steel. Bottom plates are of mild steel to enhance the lateral buckling strength. As for transverse structural members, higher tensile steel is applied at the high stress areas in connection with good structural details to avoid the extraordinary thicker plating. The total usage of the higher tensile steel of HT32 grade is limited to about 35% of total hull steel weight.

2.3 Robust Hull Structure

Failure in hull girder strength may cause a fatal accident. By this reason, the importance of reliable hull girder strength shall be emphasized. The new design of HHI's Suezmax class tanker provides sufficient hull girder bending moment capability by securing with 10% marginal still water bending on top of the most critical loading case. This design concept will ensure that HHI's Suezmax class tanker may survive even in more harsh environments than the design criterion specified by Classification Societies or it can be expressed that she may endure an unexpected cargo loading condition due to mis-operation of cargo loading.

Most Shipowners are not ready to accept restriction in cargo filling ratio due to sloshing. The structures of cargo tank boundaries in HHI's Suezmax class tanker design are reinforced to allow any level partial filling in all cargo tanks with the cargo of specific gravity up to 1.025.

2.4 Enhanced Structural Details

One of the most critical joints in double hull tanker structures is the hopper corner due to high stress concentration. Fig.3 shows details of the hopper corner structure in HHI's Suezmax class tanker design. Special attention has been paid in alignment of interconnecting members of inner bottom plate, hopper plate and longitudinal girder plate to avoid additional stress concentration by misalignment. Big scarfing structure is also provided at inside of the hopper to release the stress concentration at the hopper corner.

It has been well proven by damage records as well as by theoretical analyses that the T-type section of the longitudinal stiffener is superior in fatigue strength to the unsymmetrical section of the stiffener. HHI's Suezmax class tanker design is adopting longitudinal stiffeners of T-type section for almost all areas as shown in Fig.4.

Cracks are most likely to be initiated from structural toes due to high stress concentrations. Special attention has been paid to the toes of primary structural members to minimize the stress concentration by tapering thickness sufficiently, grinding edge smoothly, penetration welding, and long tapering. Fig.5 shows typical details for the toe of primary structural member.

Lots of cracks have been reported at slot area where the longitudinal stiffeners and transverse primary members are intersected. HHI's Suezmax class tanker design adopts a slit type connection in extensive areas as shown in Fig.6. The slit type intersection provides a robust connection between the longitudinal stiffeners and the primary transverse members, and will reduce the possibility of the crack compared with the conventional type slot with a collar plate.

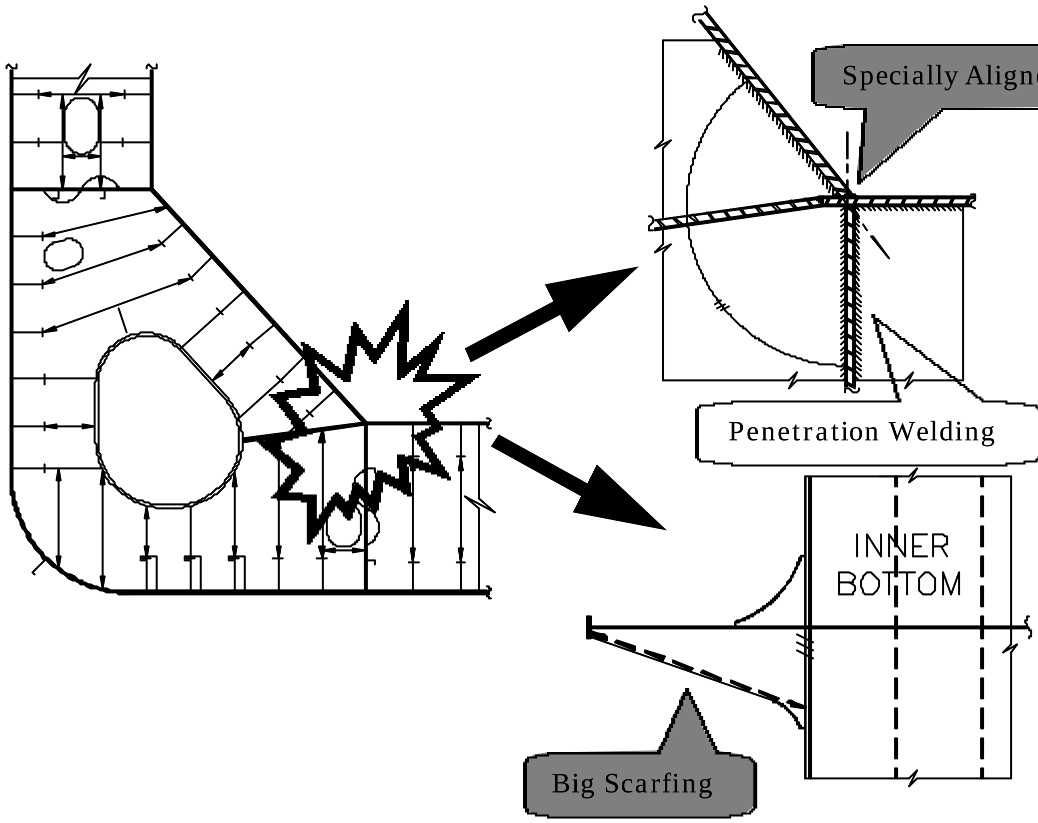


Fig.3 Structural detail of hopper corner

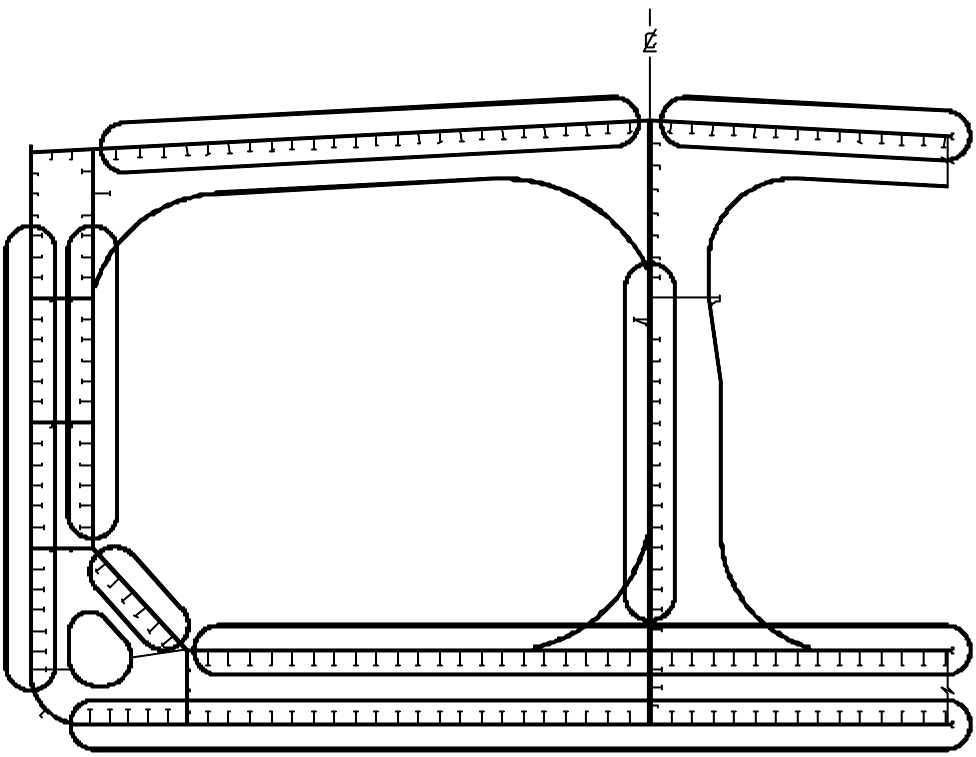


Fig.4 Application of T-type section longitudinal stiffener

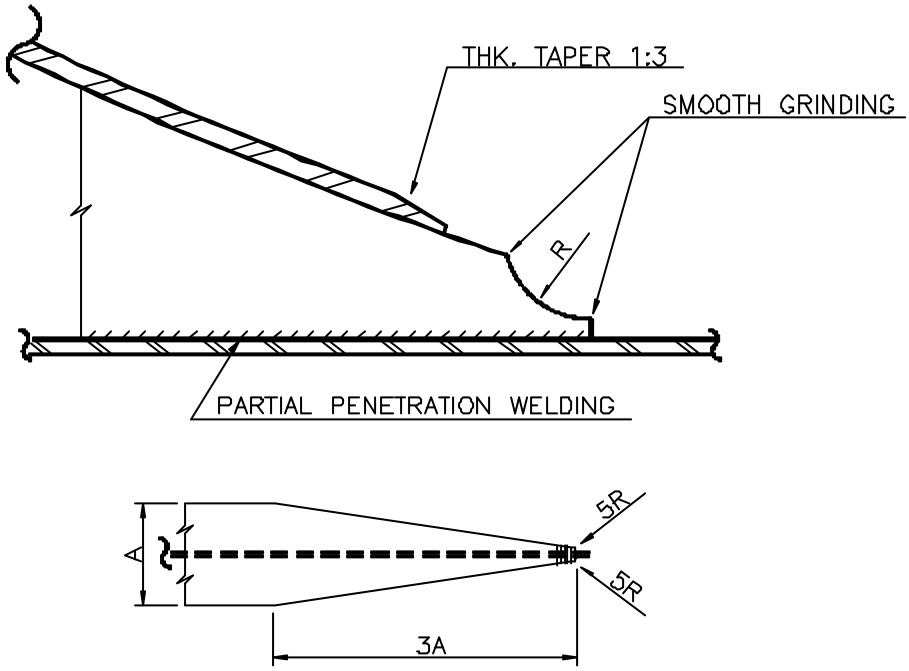


Fig.5 Typical soft toe details of primary member

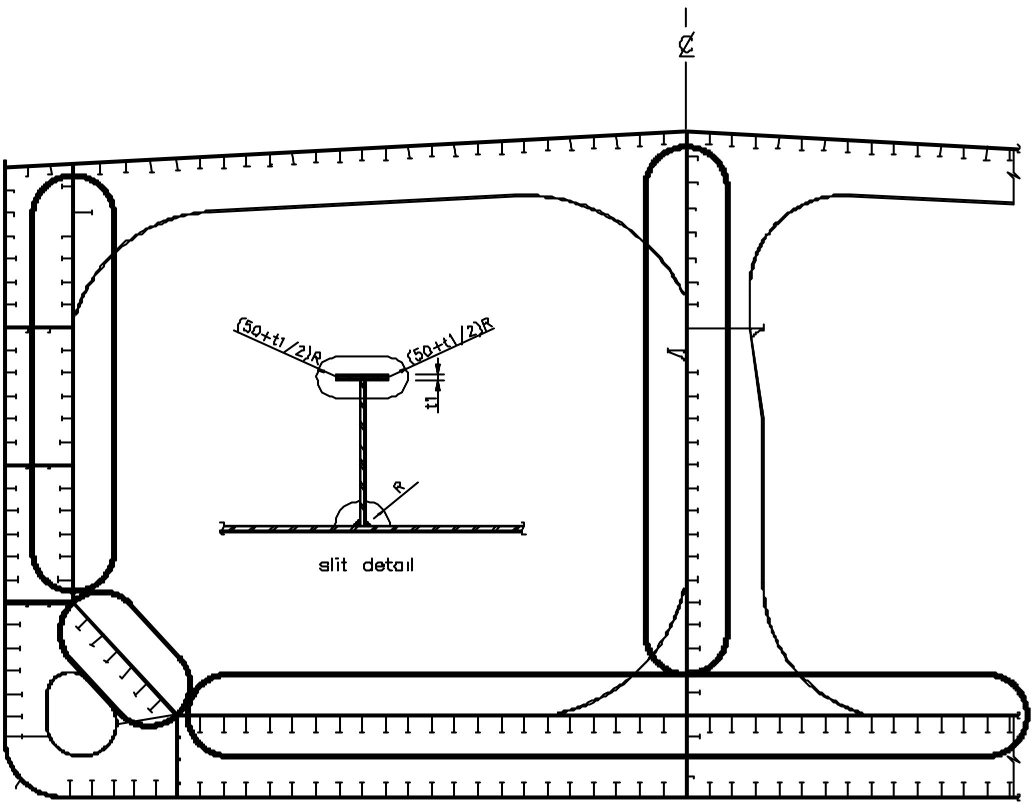


Fig.6 Application of slit type connection and slit detail

2.5 Assessment of Fatigue Strength

For the subject new design, structural connections of the longitudinal stiffener are designed to meet with the requirements of minimum 30 year fatigue life according to the current calculation procedure set-up by the selected Classification Societies. In addition, the fatigue strength of the structure is assessed rationally with an enhanced design S-N diagram (HD S-N Diagram), which incorporates the effects of re-distributed residual stress and mean stress induced by the static load.

Present design S-N diagrams, which are proposed by Classification Societies, for the fatigue strength assessment of ship structures are in general derived from the research results for other industries such as steel bridge and offshore structure. It should be noted that, in ship structure, not only structural details in geometry and material but also loading patterns of dynamic and static loads are different from those of other structures. Therefore it is necessary to produce new S-N data suitable for ship structures considering the characteristics of the loading.

HHI has carried out the fatigue tests under various static load conditions for several typical fillet weld joints in ship structure.[1] The re-distribution of initial welding residual stresses due to static pre-load has been evaluated. Fatigue tests have been performed to investigate the effects of re-distributed residual stresses and mean stresses induced by static loading. Based on the fatigue test results, HHI have derived an equation of HD S-N Diagram individually, which incorporates the effects of re-distributed residual stresses and mean stresses due to the static load. The HD S-N Diagram is formulated with hot spot stress values as described in equation (1) and applicable to the evaluation of the fatigue strength of various weld joints with a unified S-N curve. Fig.7 and 8 show examples of HD S-N Diagram under various static load conditions. The slope of the S-N curve changes depending on the static load condition.

$$\mathrm{Log}N = C + m \log \Delta\sigma_{spot} - 2s \qquad (1)$$

where,

$$C = \frac{(14.415 - 3.776 \log \Delta\sigma_{same}) \cdot \log \Delta\sigma_{m,\,limit} - \log(5E6) \cdot \log \Delta\sigma_{same}}{\log \Delta\sigma_{m,\,limit} - \log \Delta\sigma_{same}} \qquad (\Delta\sigma_{spot} < \Delta\sigma_{same})$$

$$= 14.415 \qquad (\Delta\sigma_{spot} \geq \Delta\sigma_{same})$$

$$m = \frac{\log(5E6) - (14.415 - 3.776 \log \Delta\sigma_{same})}{\log \Delta\sigma_{m,limit} - \log \Delta\sigma_{same}} \qquad (\Delta\sigma_{spot} < \Delta\sigma_{same})$$

$$= -3.776 \qquad (\Delta\sigma_{spot} \geq \Delta\sigma_{same})$$

s = standard deviation of log N (= 0.181)

$\log \Delta\sigma_{same} = (0.1959\alpha + 1) \log \Delta\sigma_{0,limit}$

$\log \Delta\sigma_{m,limit} = [(0.0284\alpha^2 + 0.0232\alpha + 1) + (1.285\beta^2 - 2.609\beta)(0.0284\alpha^2 + 0.0232\alpha)] \log \Delta\sigma_{0,limit}$

α = magnitude of tensile pre-load ($\sigma_{load,\,spot} / \sigma_o \geq 0$)

in case of compressive pre-load, $\alpha = 0$

β = magnitude of tensile mean stress ($1.0 \geq \sigma_{mean,spot} / \sigma_{load,spot} \geq 0$)

in case of compressive mean stress, $\beta = 0$

$\Delta\sigma_{0,limit}$ = fatigue limit under as-welded condition (= 110.438 MPa)

σ_o = design yield stress (= 235 MPa)

$\sigma_{load,spot}$ = magnitude of hot spot stress by pre-load (design load in general)

$\sigma_{mean,spot}$ = magnitude of hot spot stress by static load related to concerned load condition

[1] Refer to ACKNOWLEGEMENT

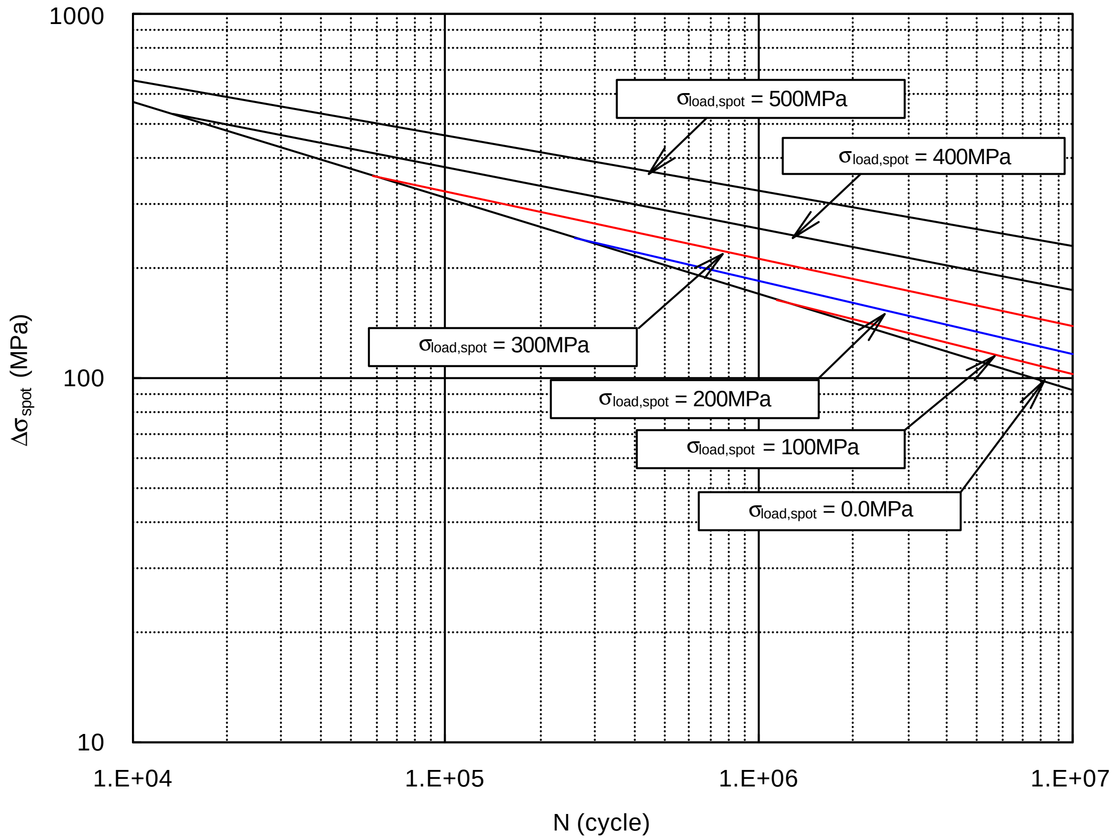
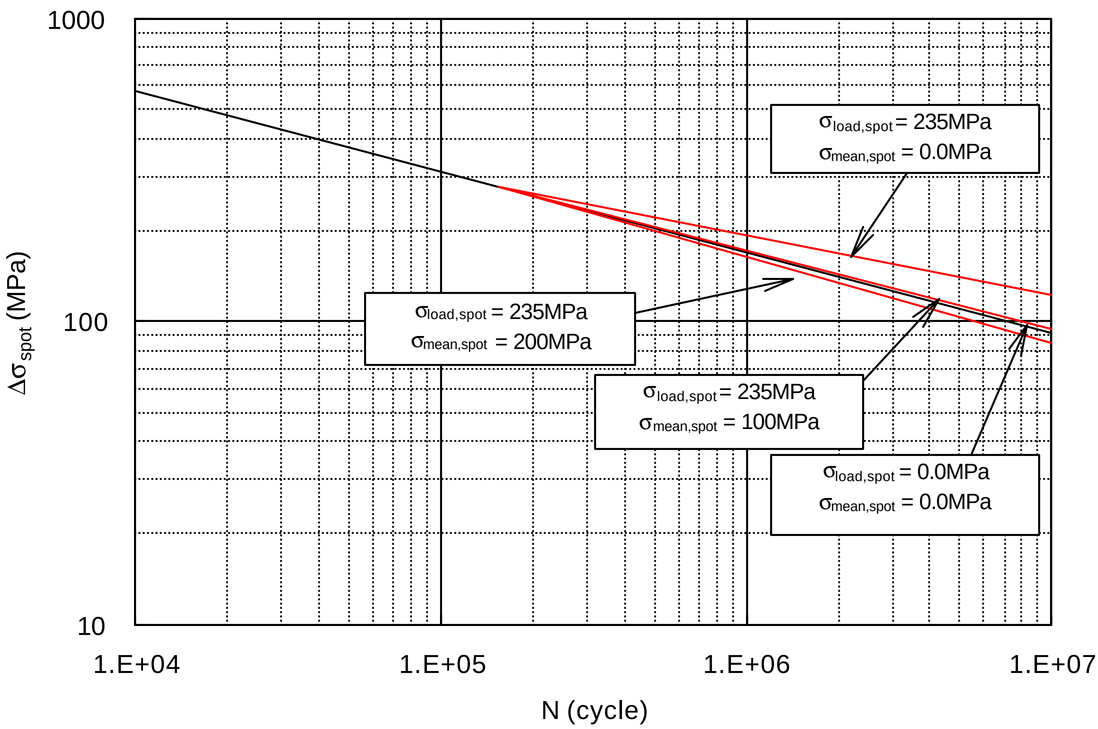


Fig.7 HD S-N Curves under various tensile pre-loads



3. ACCESS FOR CLOSE-UP SURVEY

It is imperative to ensure the long-term operability of ship structure that a planning of maintenance and repair should be implemented. The success of any planned maintenance scheme depends on the vigilance of surveyors and timely repair of any defects. This can only be achieved with an adequate system of access manholes, ladders and walkways being incorporated into the ship structural design for the effective close-up survey.

HHI's Suezmax class tanker design basically provides three(3) horizontal stringers at double side space. Maximum 5.9-meter height between adjacent stringers enables close-up survey utilizing a stretchable aluminum ladder, which can be carried and handled by only two(2) surveyors. Double bottom space has no obstruction except one(1) row of the side girder, and the 3-meter high double bottom is very convenient to inspect and to walk inside. Opening size for the main passage is 600 x 800 mm as a minimum, and as large as 600 x 1,500 mm where the stress levels are low. Fig.9 shows the conceptual passage in the structural design.

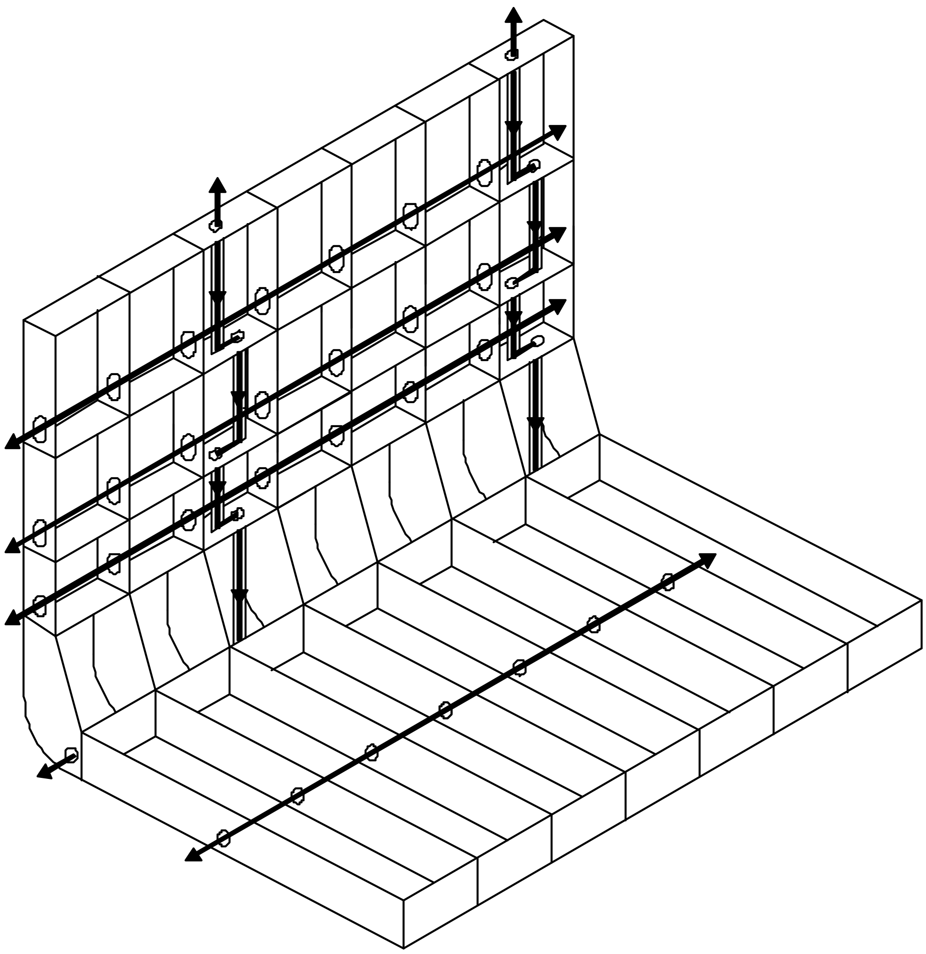


Fig.9 Passages in double hull structure for close-up survey

4. AFTER DELIVERY SUPPORT

Though the builder has poured its best effort into the design and construction work to deliver the best quality ship, it seems inevitable for the Shipowner to encounter some minor troubles of the hull structure when the ship continues her operation. HHI considers, therefore, an efficient After Delivery Support is as important as a good design/construction work and its After Sales Service Department is dedicated to minimize the Shipowners' inconvenience by solving the problem as soon as possible.

Apart from the normal guarantee service in accordance with the terms and conditions of Warranty of Quality clause of shipbuilding contract, HHI provides a "Lifetime Service" to its clients who own and operate the ships built by HHI. As its name implies, "Lifetime Service" is to provide the clients a satisfactory service throughout the lifetime of their ships and it includes a technical service such as providing shipyard's calculations, drawings, information of sub-contractors, and etc. at reasonable cost or free of charge depending on the scope of the requests. HHI has been building up a comprehensive database covering fundamental technical data and information of all HHI-built ships since its inauguration in 1973 and it plans to expand the resources in order to respond to the various demands of the clients.

Another important mission of After Delivery Support work is providing a momentum to the respective departments of HHI or its sub-contractors to improve their workmanship and not to repeat the same or similar mistakes in the forthcoming projects. After Sales Service Department of HHI operates an efficient regular feed-back system which brings the issues of the important claim reports to the design offices, workshops and its sub-contractors at least twice a month. The feedback information includes the details of the trouble, Shipowner's point of view on the cause of trouble and advice on possible solution, and etc. After assessment of the feedback information, all recipients must report back to the After Sales Service Department how/what they will modify and improve their standard practice and workmanship. All feedback files consist in the HHI database and contribute upgrading the overall quality of HHI-built ships.

ACKNOWLEGEMENT

A joint industry project to assess the fatigue capacity of 'Floating Production, Storage and Offloading units' is established by DNV under the name of 'FPSO JIP – Fatigue Capacity'. The objective of this project is to provide data to obtain a reliable design basis that can be used to ensure sufficient fatigue capacity of FPSO units. This is to avoid costly maintenance during in-service life. Eighteen(18) companies including oil companies, classification societies, engineering companies, a governmental organization and shipbuilders have joined the JIP. HHI, as a participant in the JIP, has performed the fatigue tests with small specimens of typical fillet weld joints in ship structure to investigate the effect of mean and residual stress on fatigue strength, which is one of the main tasks in the JIP.