



Tanker Structure Co-operative Forum

Information Paper on Cargo Tank Corrugated Bulkhead Damages of Double Hull Tankers

SUMMARY

The paper reviews current corrugated bulkhead design practise and provides details of damage experience of TSCF members. Failure modes and critical areas of high stress or stress concentration are discussed and recommendations for design improvement offered.

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1 Introduction

Corrugated bulkheads are generally utilised as the boundary between cargo tanks of small and medium sized product or chemical tankers. The corrugation provides benefits such as simplified cleaning which is highly desirable due to the operational profile of these vessel types. The last decade has seen significant innovation in the application of corrugated bulkheads to tanker design. In particular the use of corrugated bulkheads has extended to Aframax size and the size of tankers where corrugated bulkheads are fitted without bulkhead stools has also increased.

Properly designed, constructed and maintained corrugated bulkhead structures can give many years of safe and satisfactory service. On the other hand the complexity of structural configuration and difficulties of manufacture can lead to significant defects occurring which may be costly to repair.

The purpose of this paper is to share the defect experience of TSCF members with a view to contributing to an improvement in the structural performance of this structural configuration.

2 Terminology

Terminology used throughout the paper for parts of the corrugation is defined in Figure 1.

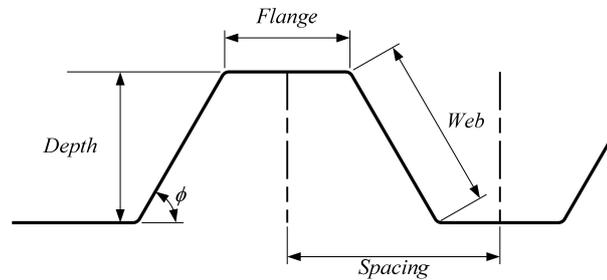


Figure 1 Corrugation terminology

Corrugations can either be fabricated or cold formed (Figure 2). Fabricated corrugations are produced by welding web and flanges together. Cold-formed corrugations are produced from a single sheet of material and pressed into the corrugation shape by mechanical means.

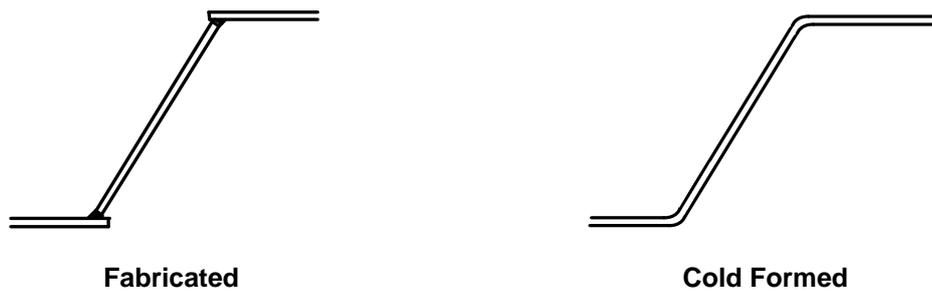


Figure 2 Types of corrugation

The angle of the corrugation web, ϕ , to the corrugation flange can also vary. Classification Rules generally prohibit the use of an angle of corrugation web to less than 55 degrees (Ref 1). Corrugation web angles up to 90 degrees have been adopted on oil tankers.

3 Typical Arrangements

Corrugated bulkheads can be categorised into two main groups based on the orientation of the corrugation; those with the corrugation orientated vertically and those with the corrugation orientated horizontally. Both types of orientation are found on transverse and longitudinal bulkheads.

In this paper the following bulkhead arrangements will be discussed:

- Vertically corrugated bulkhead
 - Without stools at inner bottom – Type VC1
 - With lower stool – Type VC2
 - With lower and upper stool – Type VC3

For bulkhead types VC2 and VC3, two deck supporting structure arrangements are described

 - Deck arrangement – Type DS1
 - Deck arrangement – Type DS2
- Horizontally corrugated bulkhead
 - Bulkhead arranged transversely – Type HCT
 - Bulkhead arranged longitudinally – Type HCL

3.1 Vertically corrugated

Vertically corrugated bulkheads take three basic forms as illustrated in Figure 3. Each configuration presents various challenges in ensuring continuity of strength and load transfer to surrounding structures.

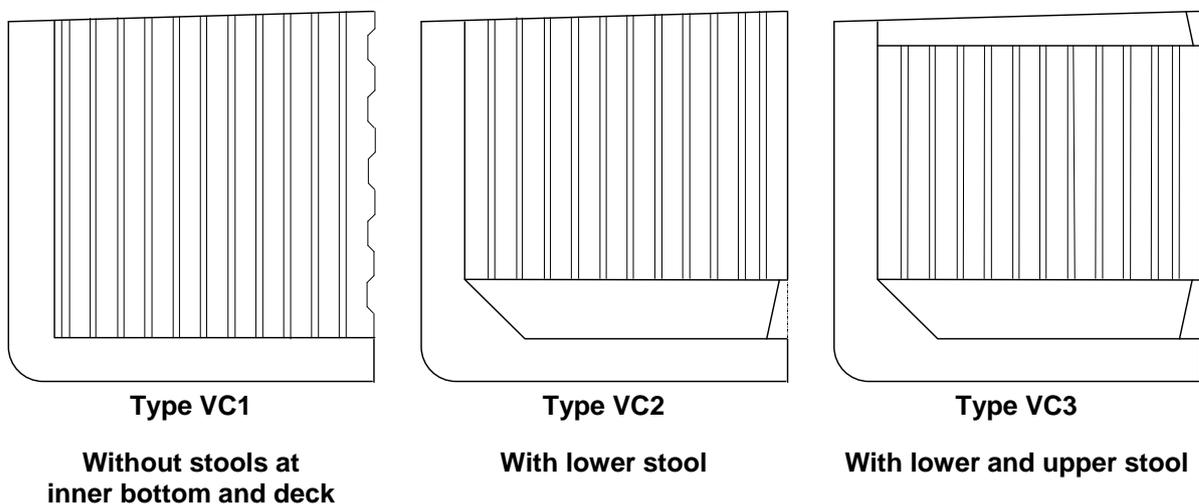


Figure 3 Configurations of vertically corrugated bulkheads

Risk associated with the formation of gas pockets in way of stools, shedder plates etc. should be considered, particularly when gas freeing the space for inspection and repair work.

3.1.1 Type VC1 – Without stools at inner bottom and deck

Type VC1 arrangement is most common on smaller tankers including product tankers and chemical carriers.

However the size of tanker on which this configuration is applied is increasing, reflecting its advantages in terms of increased cargo cubic capacity, and simplified gas freeing/ventilation issues compared to Type VC2 and VC3 configurations. This type of arrangement is permitted for ships with a moulded depth less than 16m, provided the requirements stipulated in the Common Structural Rules are complied with.

Support structure for the corrugation flanges is commonly provided under the inner bottom, by floors/girders fitted in the same plane as the flanges with load from the corrugation web transmitted through shear of the weld connection to the inner bottom, see Figure 4.

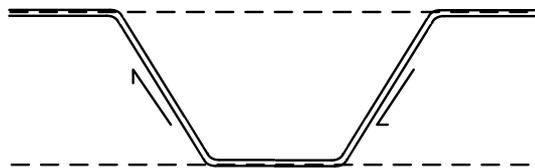


Figure 4 Support for lower end of corrugation on type VC1 below the inner bottom

For highly stressed connections support of the corrugation webs below the inner bottom by means of aligned brackets/carlings may also be arranged.

At the deck, two main types of support structure are commonly proposed depending on the design philosophy, see Figure 6.

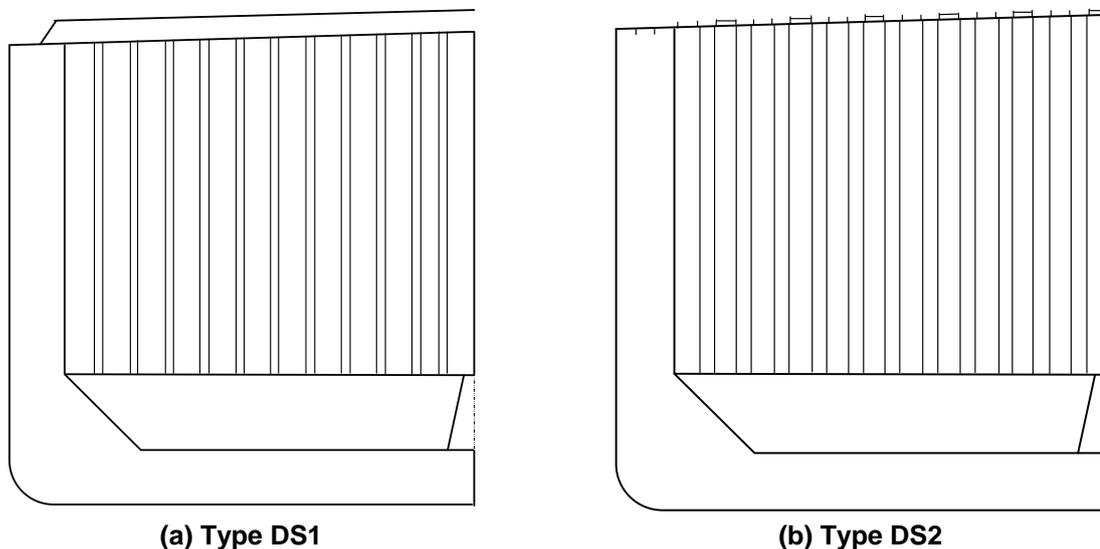


Figure 5 Types of support for upper end of corrugation on types VC1 and VC2

In Type DS1 shown in Figure 5 a, substantial above deck structure is provided consisting of girders or transverses to provide a relatively rigid support for the upper end of the corrugation. On some of these designs, additional partial girder structure is incorporated to form a grillage structure in way of the bulkhead, with the aim to reduce relative deflection, between adjacent deck transverses, see Figure 6.

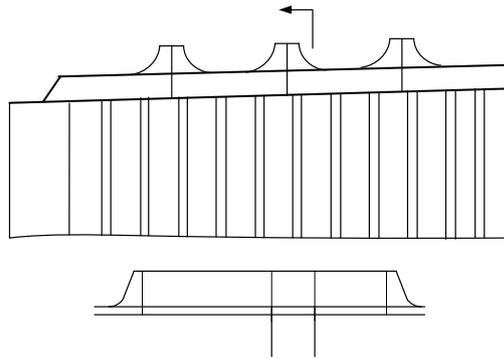


Figure 6 Schematic view of typical partial girder arrangement

Type DS2 consists of only very limited above deck structure as shown in Figure 5 b. This provides a relatively flexible support, thereby attracting less load (and therefore local stress) to the upper end of the corrugation but bigger deflection in rotation.

3.1.2 Type VC2 – With support stools at inner bottom

This arrangement is utilised on larger ships than those using type VC1 and has found application on ships exceeding 40,000 dwt. The reasons for the adoption of a lower stool include;

- to reduce the span of the corrugation in order that design stresses are not exceeded
- to reduce the size of the corrugation in order to remain within the limits of the production process
- to provide more efficient structural continuity where stresses in the design are high
- to provide efficient load transfer to the surrounding structure
- to provide appropriate shear and torsional rigidity to the lower end of the corrugation.

The support structure for the lower end of the corrugation (shown in Figure 7) is provided by means of a fabricated stool which is a box type structure. This may be of rectangular or non-rectangular cross section depending on the height of stool. The lower stool consists of shelf plate, side plates and internal web plates providing primary support for the stool boundaries. The shelf plate provides a foundation for the corrugation and facilitates load transfer from the corrugation web to the structure below through shear and also from the corrugation flanges to the stool side plates through transmission of out of plane stress.

The flanges of the corrugations are to be aligned with the side plating of the stools. For highly stressed connections support of the webs below the shelf plate by means of aligned brackets/carlings may also be arranged.

The side plates of the stool may be vertically or horizontally stiffened. Horizontal stiffening is convenient for longitudinal bulkhead stools as it provides more efficient buckling capacity to resist hull girder bending loads. Vertical stiffening is normally adopted for transverse bulkhead stools because of the simpler fabrication process, the better buckling strength and improved load transfer to the double bottom structure.

The lower stool can be either a ballast tank or void space and as such needs adequate access, drainage and ventilation. Provision of a direct access to lower stool void spaces provides particular challenges due to the sizes of opening required. Provision of openings in the shelf plate leads to a substantial reduction in its local cross sectional area which can be offset by local plate thickness increases.

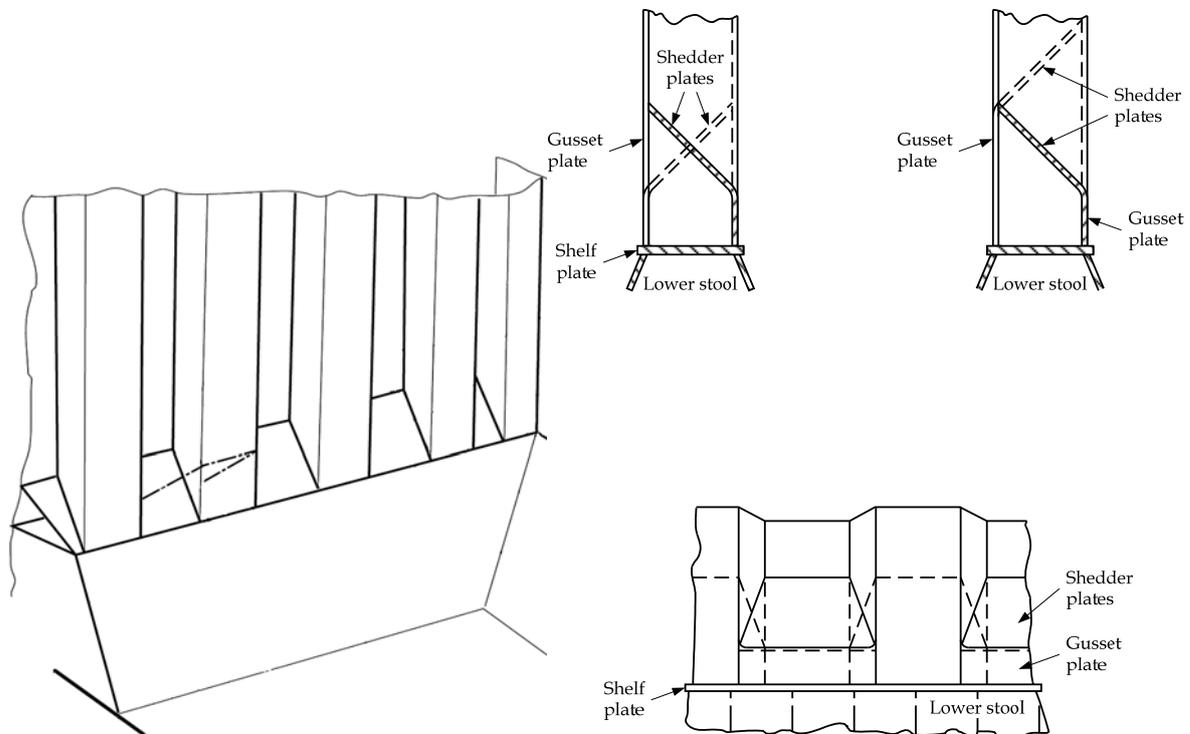


Figure 7 Lower bulkhead stool terminology

For strength or cleaning reasons, brackets or shedder plates may be arranged at the lower part of the corrugation. Special attention is to be made for the welds between those bracket and shedder plates with the bulkhead. In some cases the small volume created between the shelf plate and the shedder plate has been filled with a suitable compound compatible with the products carried by the vessel.

Attention is drawn to ships fitted with a rake of inner bottom. In most cases the floor supporting the inclined side plate of the stool is fitted with a slanted angle as regard to the ship axis in order to be aligned.

At the deck the arrangements generally follow those described for Type VC1.

3.1.3 Type VC3 – With support stools at inner bottom and deck

This arrangement is utilised on the largest tankers fitted with corrugated bulkheads which now reach Aframax size. The reasons for the adoption of a lower and upper stool include;

- to reduce the span of the corrugation in order that design stresses are not exceeded
- to reduce the size of the corrugation in order to remain within the limits of the production process
- to provide more efficient structural continuity where stresses in the design are high
- to provide efficient load transfer to the surrounding structure

- to provide appropriate shear and torsional rigidity to the lower and upper ends of the corrugation.

At the inner bottom the arrangements generally follow those described for type VC2.

At the deck, support structure for the upper end of the corrugation is also provided by means of a fabricated stool. The dimensions of this upper stool are generally less than those of the lower stool. The functions of the components of the upper stool and benefits of stiffening arrangement are similar to those described for the lower stool of VC2 type.

The space formed by the upper stool needs adequate access, drainage and ventilation. Direct access to the upper stool space from the deck is relatively straightforward; therefore it is often arranged as a void space.

Transverse corrugated bulkheads are to be properly supported inside the upper wing tank by means of a transverse support structure aligned with the corrugation flange. To further improve the connection additional diaphragms can be fitted between the flanges to increase attachment area and thus reduce peak stresses.

These additional members as well as the transverse web inside the upper wing tank should have the same mechanical properties (material grade and yield strength) as the corrugation flanges.

3.2 Horizontally corrugated

Horizontally corrugated bulkheads take two basic forms as illustrated in Figure 8.

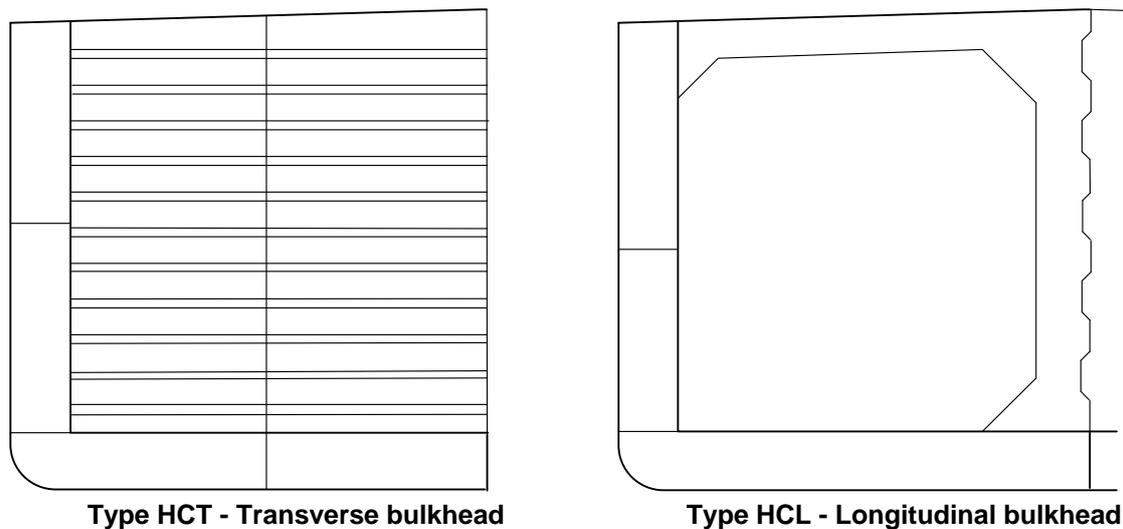


Figure 8 Configurations of horizontally corrugated bulkheads

Each configuration presents various challenges in ensuring continuity of strength and load transfer to surrounding structures.

3.2.1 Type HCT – Bulkheads arranged transversally and therefore subject mainly to local bending stresses

This arrangement is most common on smaller tankers including product tankers and chemical carriers where the efficiency of tank cleaning is of primary importance.

Unless the span (breadth of tank) is very small, some form of symmetrical vertical primary supporting member is normally provided to give adequate shear rigidity for

overall vessel transverse strength and support for the corrugations when loaded on one side.

Backing structure is normally provided to support the corrugation flanges. For longer corrugation spans, this will take the form of substantial web structures, whilst for small spans, inter-costal stiffening may be sufficient.

3.2.2 Type HCL – Bulkheads arranged on the ships longitudinal axis of hull girder bending

This arrangement is most common on smaller tankers including product tankers and chemical carriers where the efficiency of tank cleaning is of primary importance.

Continuous longitudinal bulkheads will be subjected to longitudinal hull girder bending and therefore need to be stiffened at regular intervals in order to provide adequate shear and out of plane rigidity. For this purpose vertical primary supporting members are normally arranged. These vertical primary support members are also fitted in order to provide support for the corrugations in case of one sided loading of the bulkhead.

The extreme end of longitudinal bulkheads is to be terminated at an effective bulkhead and also needs to be arranged with substantial transition brackets for the purpose of efficient load transfer and to avoid abrupt structural changes.

4 Types of Damage

4.1 Fractures

In most cases fractures are found at locations where stress concentration occurs. Weld defects or flaws are other areas where fractures are found. If fractures occur under repeated stresses which are below the yielding stress, the fractures are called fatigue fractures. In addition to the cyclic stresses induced by wave forces, fatigue fractures can also result from vibration forces introduced by main engine(s) or propeller(s), especially in the afterward part of the hull.

Fractures may also occur in way of outfitting attachments and where lifting lugs used during ship construction are fitted in high stress areas and not properly removed.

Fractures may not be readily visible due to lack of cleanliness, difficulty of access, poor lighting or compression of the fracture surfaces at the time of inspection. It is therefore important to identify, clean, and closely inspect potential problem areas. If the initiation points of a fracture are not apparent, the structure on the other side of the plating should be examined. Fractures initiating at latent defects in welds more commonly appear at the beginning or end of a run of welds, rounding corners, or at an intersection. Special attention should be paid to welds at the base of corrugations, at scallops/cut-outs, and at intersections of welds. Fractures may also be initiated at welds with an extreme undercut.

Typical locations susceptible to higher stress levels and misalignment are listed below. Such locations will then, by their nature, be at risk of damage unless appropriate measures are taken at the design stage:

- Typical small tankers
 - Transverse Bulkhead – Vertically Corrugated
 - Connection of corrugation to inner bottom
 - Connection of corrugation to deck
 - Connection of deck longitudinals to corrugations
 - Transverse Bulkhead – Horizontally Corrugated
 - Connection of corrugation to longitudinal bulkhead and inner hull.
 - Connection of inner bottom and bottom shell longitudinals to floors in way of the lower stool
- Typical larger tankers
 - Transverse bulkhead – Vertically Corrugated
 - Connection of lower stool to inner bottom plating.
 - Connection of lower stool to lower shelf plate.
 - Connection of vertical corrugations to lower stool plate.
 - Connection of vertical corrugations to upper stool plate.
 - Connection of longitudinal deck girder system to upper stool.
 - Connection of upper and lower shelf plates to stool.

Note: The details listed above are for guidance and should not be taken as a complete list. Appendix 1 lists typical defects and locations.

4.2 Buckling

Buckling is caused by excessive compressive and/or shear stresses resulting in out-of-plane deformation. The buckling strength of a plate depends on the ratio of thickness to stiffener spacing. In the case of corrugated bulkheads the stiffening of the flange is made by the corrugation web. Buckling can therefore occur:

- Where corrosion has reduced the steel thickness, and hence the buckling strength.
- Where high loads have caused distortion (e.g. over-pressurisation, contact damage etc).
- When the welds between the components of the corrugation are degraded by corrosion, leading ultimately to detachment and reduction in buckling strength.
- Where initial deformation has reduced the buckling strength.

Once buckling has started, collapse may progress rapidly due to the relatively low ultimate strength capacity of the corrugated bulkhead panel. Corrugated bulkheads have a relatively low ratio of ultimate load carrying capacity compared to its elastic load carrying capacity. Typically the plastic moment transmitted by a corrugation is only 1.2-1.3 times the maximum elastic moment.

Local buckling is most commonly found towards the upper part of horizontally corrugated bulkheads where loads from over pressurisation are most significant.

Elastic buckling will not normally be directly obvious but may be detected by evidence of coating damage, stress lines or shedding of scale. Buckling damages may also be found at the intersection between longitudinal and transverse corrugated bulkheads.

4.3 Deformation

In addition to the deformation caused by buckling, deformation of structure can also be caused by out-of-plane loads or a combination of loads. Such deformation is often identified as local deformation, i.e. deformation of panel or stiffener, or global deformation, i.e. deformation of beam, frame, girder or floor, including associated plating.

Deformations are often caused by impact loads/contact and inadvertent overloading.

4.4 Material Wastage

Material wastage of corrugated bulkheads on double hull tankers is relatively low. Corrugated bulkheads are generally fitted to product or chemical tankers and are therefore fully coated, well maintained and not subjected to mechanical wear.

The surface of corrugations is almost free from surface stiffening which means that the incidence of grooving is reduced compared to stiffened structures where regular patterns of drainage can develop. However where brackets or outfit items such as access ladders or pipework are attached to bulkheads, accelerated corrosion can occur in way of coating breakdown at the attachment points.



Figure 9 Accelerated corrosion in way of attachment points

Internal corrosion of stool spaces is possible in way of coating breakdown particularly where these spaces are arranged for the carriage of water ballast.

5 Recent Damage Experience

Appendix 1 shows example damages reported by TSCF members. For each damage case, probable causes are identified according to the categories described in this section.

5.1 Damages due detail design

Detail design refers to the part of the design process, where attention is paid to minimisation of stress concentrations in highly stressed locations. Damages due to detailed design occur in highly stressed areas of corrugated bulkhead as summarised in Table 1: . Other examples of damage related to detailed design are shown in Appendix 1, Case 1.2 and Case 1.8.

Table 1: Detailed design damage listing

Highly stressed area	Example damage
In way of backing structure below the connection of the lower part of the corrugation to the adjacent structures	Appendix 1, Case 1.4
In way of backing structure above the connection of the upper part of the corrugation to the adjacent structures	Appendix 1, Case 1.5 Appendix 1, Case 1.6
In way of intersections of longitudinal/transverse bulkheads	Appendix 1, Case 1.1
Arrangements in way of longitudinal structures forming part of corrugated bulkhead supports	Appendix 1, Case 1.6

5.2 Damages due insufficient support

Provision of direct support for the ends of corrugations is important for all design types. This is especially true for the lower end of the corrugation which has relatively high end fixity due to the relative stiffness of the double bottom structure and variation of buoyancy loading on the bottom shell. The high end fixity is associated with high loads and it is therefore essential to provide adequate support.

In all types of corrugated bulkhead design, the support arrangements generally represent a compromise in providing a structure compatible with production methods, whilst achieving a satisfactory level of load transfer between adjacent structural members.

In this paper, damages associated with insufficient support are associated with a lack of support for the corrugation flange. Such damages are not only limited to the connection to the inner bottom, but can also be found where the corrugation lands on sloping plating.

Example damages due to insufficient support are shown in Appendix 1, case 1.9 and case 1.10.

5.3 Damages due to lack of continuity

The typical arrangements of corrugated bulkheads referred to in section 3, present challenges to ensuring continuity of strength. When support is only provided for the corrugation flange an increased stress concentration at the corners of the corrugation flange is created. This increased stress concentration does not necessarily lead to damages provided design stress is low or detailed design calculations are made.

Example damages are shown in Appendix 1, Case 1.10, 1.11, 1.13 and 1.15.

5.4 Damages due to misalignment and poor fit up

Whatever design steps are taken, stress concentrations are an intrinsic feature of the as designed structure. The fabrication process has significant extra scope to magnify intrinsic stress concentrations or introduce new ones due to misalignment and poor fit up.

At the ends of the cargo hold, where the hull shape results in changes to the height and slope of hopper structure, fit up of the corrugation and alignment of backing structure can be problematic.

Example damages are shown in Appendix 1, Case 1.16 and case 1.17.

5.5 Damages due to welding

Weld defects are themselves associated with a significant stress concentration and such defects are therefore a common source of cracks in service.

For newbuildings, according to CSR for Double Hull Oil Tankers (DHOT) increased requirements to welding (partial or increased fillet) apply to highly stressed connections in tension. Examples of locations are listed below.

- connection of hopper to inner hull
- longitudinal/transverse bulkhead primary support member end connections to the double bottom
- connection of corrugated bulkhead lower stool side plates to shelf plate and inner bottom/hopper tank
- connections of gusset plates to corrugated bulkheads
- connection of double bottom floors, lower hopper tank webs and double bottom girders below corrugated bulkhead flanges and gusset plates for corrugated bulkheads configured without lower stools
- structural elements in double bottoms below bulkhead primary support members and stool plates.

Full penetration welds are required at the following connections:

- lower end of vertical corrugated bulkhead connections
- lower end of gusset plates fitted to corrugated bulkheads

It should be noted that only full penetration welding can be inspected through the whole thickness by ultrasonic testing.

Example damages are shown in Appendix 1, Case 1.17 to 1.23.

5.6 Damages due to trough thickness lamellar tearing

Lamellar tearing is a crack parallel to the rolled surface of steel plates in layers after welding. This is caused by welding stress, non-metallic inclusions in the plate, etc and it will be extended by further tensile strain in a direction perpendicular to the rolled surface. Such damage had been found mainly at inner bottom plates in way of corrugated bulkhead or stool shelf plating where full penetration welding had been employed and similar areas. Recently such incidents of damage have become less frequent because of improvements in quality, even for normal steel plates. However, the problem can still occur in steel made by older types of processes.

Under such circumstances, IACS CSR for DHOT requires consideration to be given to the use of special material (Z-grade steel) with specified through thickness properties for such areas. The interpretation of this requirement, however, shows the use of such material is not required in general according to the usual building standards and should be decided considering the level of tensile strain in direction perpendicular to plate and the plate thickness for avoiding lamellar tearing.

It is important to control the sulphur level of steel used in these areas, as a high sulphur content will create soft layers which will contribute to lamellar tearing, regardless of the thickness of the plate material.

6 Recommendations

The IACS CSR for DHOT include a requirement for full penetration welding to be adopted at the connection of the lower end of the corrugation to the shelf plate and for the connection of stool side plates to the shelf plate. The corrugation material thickness is determined based on rule formulations with a permissible stress of approx 75% of yield stress for static load and 85% for static plus dynamic loads. For a Rule minimum structure, the stresses at the intersection of the corrugation with the shelf plate will be close to the rule permissible stress levels because of the relatively high end fixity at the base of the corrugation.

If fillet welding is used the associated stress concentration of around 2.4 has the potential to take the actual stress levels well beyond the yield strength of the material. For this reason full penetration welding is required by the Rules. A further consideration for the weld design is that the corrugation will be subjected to cyclic stress during the life of the ship, which means that the fatigue properties of the welded joint will also have an influence on its eventual design life. Additional brackets may also offer a solution. A bracket in way of the lower stool connection to the inner bottom at every girder location is an option to reduce the stress concentration.

The recommendations below are made based on experience of TSCF members in order to promote an improved standard above the Rule minimum.

6.1 Design

At the early stage of corrugated bulkhead design, attention should be paid to the arrangements for providing continuity of support for the flanges of the corrugation. Choice of material has implications for the overall stress level in the structure, which should be taken into account when considering the transfer of loads between adjacent thicknesses.

Ideally, web diaphragms should be arranged directly in line with the corrugation webs. On designs without a stool, this is rarely possible as such arrangements would interfere with the longitudinal stiffening arrangement.

If shedder plates are placed on fore and aft side of the bulkhead, they should be arranged so they do not cross, in order to avoid hard points at the corrugation webs.

The following table outlines the highly stressed areas in typical corrugated bulkhead designs and provides examples of detail design improvement.

Table 2: Highly stressed areas

Highly stressed area	Example detailed design improvements
In way of backing structure at the ends of the corrugation at the connection to the adjacent structures	Minimise changes of thickness at intersections of members
	Close scallops or holes in way of corrugation flange and web
	Increase throat thickness of weld details
In way of longitudinal structures forming part of corrugated bulkhead supports	Pay attention to shape and profile of bracket toes at the fore and aft ends of longitudinal structures to minimise risk of fatigue

6.1.1 Arrangements in way of vertical corrugation lower end connections

6.1.1.1 Type VC1 – Without lower stool at inner bottom

Attention should be paid to the support and continuity of strength at the base of the inner bottom.

Direct backing structure for the corrugation flange is always to be provided. In cases where direct support of corrugation web is not provided, then it should be ensured that the inner bottom thickness is at least half the attached corrugation thickness, to provide a practical thickness for heat absorption during welding.

Where the inner bottom material strength is less than that of the attached corrugation, the design of backing structure should consider the increased stress levels being absorbed in the support structure.

Scallops or drainage holes in backing structure below the corrugation flange are to be avoided.

To minimise stress concentrations at the critical weld connection of corrugation flange to inner bottom, the backing structure should be the same material thickness and grade as the corrugation flange.

6.1.1.2 Type VC2 & VC3 – With lower stool at inner bottom

Attention should be paid to the support and continuity of strength at the base of the corrugation. Ideally the corrugation dimensions, internal web spacing and stool stiffener arrangement should be chosen to allow full backing structure to be provided in way of the corrugation webs.

To minimise stress concentration at the critical weld connection of corrugation flange to shelf plate, the stool side plates should be the same material thickness and grade as the corrugation flange.

Where it is not possible to provide full backing structure for the corrugation web, consideration should be given to increasing the stool shelf plate thickness to enhance the load transfer capacity.

6.1.2 Arrangements in way of vertical corrugation upper end connection

6.1.2.1 Type VC1 & VC2 – Without upper stool at deck

Where it is proposed to provide substantial backing structure for the upper end of the corrugations, all openings in the web of the deep transverses are to be closed.

Backing structure is to be provided to avoid the creation of hard spots.

Design of above deck structure is to consider a smooth change of section with respect to longitudinal strength and fatigue.

Where it is proposed to provide a flexible connection at the upper end, careful consideration of the corrugation dimensions will be required in relation to the deck longitudinal stiffener spacing. Intercostal stiffeners between deck longitudinals are to be fitted in way of corrugation flanges.

Where corners of corrugations impinge on unsupported plate, the stresses associated with local plate bending are to be considered.

The overriding requirement to provide continuity of strength of the deck longitudinal often means that it is impractical to provide complete backing structure for the corrugation web. A backing stiffener along the line of the corrugation webs is recommended even if these cross the longitudinal deck stiffeners.

6.1.2.2 Type VC3 – With upper stool at deck

Where longitudinal deck stiffeners or girders are fitted above deck and pass over stool side plating, tripping support brackets are to be provided at the intersection.

Design of above deck structure is to consider a smooth change of section with respect to longitudinal strength and fatigue.

Drainage holes arranged in brackets fitted above the corrugation shelf plate are to be arranged clear of the corrugation flanges. Where scallops are used to facilitate fit up, these are to be closed by lapped closing plates.

6.1.3 Arrangements in way of horizontal corrugation end connections

6.1.3.1 Type HCL – Bulkheads arranged on the ships longitudinal axis of hull girder bending

Support should be arranged at the end of the corrugation for both corrugation flanges, preferably in the form of deep webs or brackets with a depth of at least one third of the corrugation span. Diagonal support for the corrugation webs should also be considered.

It is recommended to apply full penetration weld at forward and aft end of the bulkhead.

6.1.3.2 Type HCT – Bulkheads arranged transversally and therefore subject mainly to local bending stresses

Support should be arranged at the end of the corrugation for both corrugation flanges, preferably in the form of deep webs or brackets with a depth at least one third of the corrugation flange breadth. Diagonal backing structure for the corrugation webs should also be considered where these can be integrated efficiently with the side bulkhead stiffening.

6.1.4 Arrangements in way of primary support members

Where vertical primary support members are arranged these should be aligned with suitable web structure in the inner bottom and above deck. Where backing brackets are fitted, arrangements should be provided to ensure that the bracket toe is supported.

The primary support member should not be in between the flanges of the corrugation.

6.2 Construction

Controls with enhanced dimensional control and tolerance limits should be put in place to ensure that the fabricated structure corresponds closely to the design intent.

6.3 Repair

Where repairs are required to defects arising, improvements to the original design should always be considered in-order to avoid a repeat occurrence. Such changes include increasing the thickness of plates at intersection points, increasing weld sizes, reducing use of scallops

7 References

1. IACS Common Structural Rules for Double Hull Oil Tankers