El caso del B/t “Prestige”

Introducción:

Datos generales (SIC):
IMO Number: 7372141
Built: 1976 at Hitachi Shipbuilding & Engineering Co. Japan
Owner: Mare Shipping Inc., Registered in Liberia
Manager: Universe Maritime Ltd., Greece
Class: ABS - Built and maintained to ABS class
Flag: Bahamas
Marpol 13G
Phase out Date: 11 March 2005
Design
Deadweight: 81,589 tonnes
Gross Tonnage: 42,820
Sister Vessels: None in service
Statutory Certification: ABS on behalf of Bahamas with exception of ISM certification, issued by Bureau Veritas.
P&I Coverage: London Steamship Owners Association
Pollution Liability Coverage: The operators state that Mare Shipping is fully covered for ship owner's pollution liability within the International Oil Pollution Compensation Fund.
Notes: The vessel was constructed of mild steel.

The vessel was subject to the IACS Enhanced Survey Program (ESP)

The vessel was a Category 1 vessel under MARPOL 13G requirements, approved for either Hydrostatic Balanced Loading (HBL), as a crude oil tanker, or CBT with 30 percent side or bottom protection, as a product tanker. Information provided by the operator shows the vessel was loaded in conformance with the CBT requirements at the time of the casualty.

Also Note: Under the US Oil Pollution Act of 1990, single hull tankers without either double sides or double bottoms of 30,000 gross tons and larger are not permitted to trade in US ports after 1 January 2000. However, the Prestige would have been permitted to carry cargo to the US until 1 January 2015 provided it was offloaded either at a licensed deepwater port (LOOP), or at any one of four established offshore lightering zones. These are located more than 60 miles offshore (Southtex, Gulfmex No 2, Offshore Pascagoula No 2 and South Sabine Point).

Al momento del accidente tenía 26 años de antigüedad.
Su armador era “Mare Shipping Inc.”, registrada en Liberia y estaba operado por “Universe Maritime Ltd.”, con base en Grecia.

**Croquis transversal y longitudinal del buque**

![Croquis transversal y longitudinal del buque](image)

**Cargamento y esfuerzos:**

Su cargamento era 76.972 toneladas métricas de fuel oil pesado cst 600 (gravedad específica 0,99) generalmente usado como combustible para grandes motores Diesel marinos.

La carga estaba distribuida en todos los tanques, excepto los 2 laterales de popa y los 3 laterales.

Según el plano de carga el buque había sido cargado apropiadamente y de acuerdo al cuadernillo de cargamento el máximo momento flector longitudinal era del 42% del máximo permitido en aguas calmas al momento de su zarpada de Latvia.
Sociedad clasificadora

La sociedad clasificadora era el ABS (American Bureau of Shipping) durante la construcción y posterior mantenimiento de clase. Sus certificados reglamentarios eran otorgados por el ABS en nombre de Bahamas, con excepción de la certificación ISM emitida por el Bureau Veritas. La cobertura P&I estaba otorgada por London Steamship Owners Association. Los operadores Mare Shipping declaran que el buque estaba cubierto totalmente por responsabilidad del armador contra polución dentro del International Oil Pollution Compensation Fund.

El buque estaba construido principalmente con acero dulce, y estaba sujeto al programa de inspecciones para mejoras (ESP) de la Asociación Internacional de Sociedades de Clasificación (IACS). El buque era Categoría 1 según requerimientos del MARPOL 13G, habiendo aprobado ambas pruebas:
a) *Hidrostatic Balanced Loading* (HBL) como buque tanque crudo.
b) CBT con 30% de costados o fondos protegidos, como buque productero.

Marpol 13G vencía el 11 de Marzo de 2005

El operador demostró que el buque fue cargado en conformidad con los requerimientos CBT en el momento de su accidente.

Según el acta de 1990 sobre polución de los EE.UU., los buques tanques sin doble casco (costados y fondos) o sin doble fondos de 30.000 TRB o mayores no tienen permitido el tráfico con puertos de EE.UU. luego del 1 de Enero de 2000.

Sin embargo, el "Prestige" podría haber sido autorizado a efectuar ese tráfico hasta el 1 de Enero de 2015 si previamente era alijado en algún puerto de aguas profundas autorizado (LOOP) o en cualquiera de las cuatro zonas de alijo establecidas por el gobierno de los EE.UU. Las mismas se encuentran a más de 60 millas marinas de la costa y se denominan:

a) Southtex.
b) Gulfmex #2
c) Offshore Pascagoula #2
d) South Sabine Point

Historial de las inspecciones de clase

La inspección especial (Special Survey), # 5 fue efectuada en Guangzhou, China en Mayo de 2001.

Con referencia a clase se efectuaron las siguientes tareas:

a) Dique seco
b) Inspección del portahélice
c) Inspección anual y especial de casco
d) Automatización y sistema de gas inerte.
e) Inspección anual de máquinas
f) Inspección especial continua de máquinas
g) Inspección de calderas
h) Inspección de daños y reparaciones
i) Calibraciones y exámenes

Los certificados reglamentarios renovados fueron los siguientes:

a) Inspección anual de líneas de carga.
b) Reemplazo de línea de carga.
c) Seguridad de radio (SLR).
d) Seguridad de equipo (SLE).
e) Seguridad de construcción (SLC).
f) Inspección de reemplazo del certificado internacional de polución (IOPP).
g) Inspección de cumplimiento con SOLAS regla II -1/3.3 y II -2/59.
h) Inspección de re-testeo de guinches.
Dos inspectores con las calificaciones correspondientes estuvieron a cargo del control de las reparaciones.
El control de los escantillones fue realizado por la firma Dimitros Thomas Marine Limited, cuya certificación fue emitida el 12 de Octubre de 1998 con una validez de tres años.

Información sobre inspecciones suministrada por ABS en Internet. (SIC)

Class Survey History

Special Survey No. 5: Conducted in Guangzhou China, May 2001.
Statutory Annual Load Line Inspection, Load Line Renewal, Safety Radio (SLR), Safety Equipment (SLE), Safety Construction (SLC) and International Oil Pollution (IOPP) Renewal Surveys, Survey for Compliance with Safety of Life at Sea (SOLAS) Reg II-1/3.3 and II-2/59 and Cargo Gear Re-Testing Surveys.

Two ABS surveyors with appropriate qualifications attended. The gauging firm used was Dimitros Thomas Marine Limited, whose certification was issued 12 October 1998 with a validity of three years.
The vessel was first visited on 2nd April, 2001. The overall inspection, close-up survey, thickness measurements were carried out together with the hydrostatic testing of the tank boundaries as required by the rule requirements afloat at anchorage in Guangzhou, PRC between 2nd and 10th April 2001. Thickness measurements were taken in accordance with the rule requirements during the close-up survey and witnessed by the surveyors. The certificate for the gauging technician and the calibration records were reviewed and found in order, the equipment was also verified to be in order before the thickness measurements commenced.
Upon completion of the above examinations, the vessel moved to Guangzhou Cosco Shipyards for repairs on 10th April 2001. Before commencement of the repair, the material for repair was verified against mill certificate, the material was also selected for confirmatory testing and all shown in order. The welding procedures and the welders’ qualification records, the NDT (Non Destructive Testing) equipment records and the operators’ qualifications were verified. The welding sequence, gouging process were also discussed with the shipyards quality control department and the ship owner representative.
The major repairs were undertaken in the side ballast/cargo tanks No.3 (P&S) and concentrated mostly on the transverse bulkheads and the frames at the upper levels within the tank. Accordingly, the above-mentioned tanks were fully staged at Frames 61 & 71 and between Frs.65 - 70 respectively. Staging was also extended to various areas for the repair of shell and longitudinal bulkhead longitudinals. In particular, in way of the side ballast/cargo tank Nos.2(aft) & 3, the shell plates were close-up surveyed internally and externally examined. There was no area of concern noted on the shell plate. Thickness measurement results showed that the average wastage on the shell plate was less than 10 percent. No repair was considered necessary on the shell plate at the time. The starboard shell
Longitudinals were found below 10 percent wastage in side ballast/cargo tank No.2(S) aft and the starboard shell longitudinals were found mostly between 10-15 percent wastage in side ballast/cargo tank No.3(S) at time of survey. The repair works onboard were divided into three stages: fit-up, gouging and final examination. They were carried out under supervision of the attending surveyors and found satisfactory. Upon completion of the repair, confirmatory non-destructive testing by radiographic & ultrasonic method was selectively carried out, confirmatory hydro-test and air-tests were also carried out and all found satisfactory. The repair/testing was completed on 19 May 2001. Total steel replaced is estimated at 362 tonnes. The repairs that were required were in accordance with those that could reasonably be expected on a vessel of this type at Fifth Special Survey.

Annual Survey: Conducted in Dubai, UAE.
The vessel's last Annual Class Survey and Statutory Surveys were carried out by the Dubai office of ABS while the vessel was in the Fujairah anchorage, UAE, in May 2002. The survey was commenced on May 15. All repairs were completed to surveyor's satisfaction and the appropriate certificates were issued on 25 May 2002.

Class Surveys: Annual surveys of Hull, Machinery, Automation and Inert Gas System.
Statutory Surveys: Annual Load Line Inspection; SLR - Periodical; SLE - Annual; SLC - Annual; IOPP Annual; Annual Cargo Gear.

Port State Control Inspections:
Interrogation of the Equasis database indicates the following PSC inspections were undertaken:
1 Sept 1999, Rotterdam No detentions; 2 Life saving related deficiencies, 1 General deficiency
25 June 1999, Baltimore No detentions, no deficiencies
19 May 1999, Long Island (US) No detentions, no deficiencies
19 April 1999, New York No detentions, one navigational related deficiency
15 April 1999, Long Island (US) No detentions, no deficiencies
28 Nov 1998, Port Hawksbury No detentions, no deficiencies
Lloyd's Seasearcher database reports one previous casualty, in 1991, involving a fouled propeller.

Inspección anual
La última inspección anual de clase fue llevada a cabo por la oficina del ABS de Dubai mientras el buque se encontraba en el fondeadero de Fujairah, Union de los Emiratos Árabes, en el mes de Mayo de 2002. La inspección se inicio el día 15 de mayo y todas las reparaciones solicitadas fueron completadas a satisfacción de los inspectores y los certificados emitidos el 25 del mismo mes.

El accidente:
Aproximadamente a las 14:00 hora local del Miércoles 13 de Noviembre de 2002, el buque que navegaba con mar muy gruesa fuertes vientos (se indican
fuerza Beaufort 10/11 – 23,3 a 27,1 m/s), en proximidades del cabo Finisterre, entre 25 a 30 millas náuticas de la costa gallega, sufre una escora a estribor reportada de 25°. Los reportes de las autoridades de Bahamas informaron que el buque experimentó una repentina vibración previa a la escora.

Un análisis posterior de la estabilidad del buque mostraron que una repentina inundación de los tanques 2 y 3 de estribor crearon dicha situación.

**Cargo and Flooded Compartments After Damage**

![Diagram of cargo and flooded compartments](image-url)
Un análisis de esfuerzo flector que sufría la viga buque en esas condiciones, encontrándose las estructuras del resto del buque intactas y estando en aguas calmas, era de 125%, o sea, había superado en un 25% el máximo permitido en zona protegida; pero el buque, aún en esas condiciones, poseía un brazo adrizante GZ positivo.
La estructura del buque fue capaz en esas condiciones de resistir el incremento de carga y permanecer a flote.

Veinticuatro de los veintisiete tripulantes del buque (filipinos y rumanos) fueron evacuados mediante helicópteros, permaneciendo a bordo el Capitán, Primer Oficial y Jefe de Máquinas.

Los tripulantes rescatados, cuando llegaron a tierra, declararon ante los medios que el buque había colisionado con un objeto sumergido que le produjo una severa vibración a la estructura del casco.

Ese dato, no confirma la evidencia de la causa inicial del daño que llevó a la inundación de los tanques laterales 2 y 3 de estribor.

El gobierno español rechazó el pedido del buque y del equipo de salvamento de llevar al buque a aguas protegidas y ordenó que el mismo debía ser llevado a más de 60 millas náuticas de la costa.
Acciones siguientes:

Los tanques 2 y 3 de babor fueron llenados con agua de mar para compensar a escora a estribor. Esta medida redujo la misma a unos 3 a 5°, siempre a estribor, pero el esfuerzo flector de la viga buque se incremento al 163%.

Cargo, Ballast and Seawater Disposition After Righting
7. STRUCTURAL STRENGTH AT THE TIME OF THE CASUALTY
To assess the strength of the hull-girder and individual structural members, finite element structural analyses of the hull structure were performed. The resulting load effects are checked with yielding and buckling failure criteria.

7.1 Structural condition of the PRESTIGE
Thickness measurements or gaugings were last conducted during Special Survey No. 5 in May 2001. The thickness measurements taken in May 2001 were used as the basis for the structural finite element model in the analysis of the PRESTIGE at the time of the casualty on 13 November 2002. The casualty occurred 18 months after these thickness measurements were conducted; it was considered that wastage would be very small over the period, and therefore the May 2001 thickness measurements were used for the structural analysis. See Section 7.5 for further discussion on corrosion wastage.

7.2 Finite element modeling
The ABS SafeHull system was used to build a 3-dimensional global structural model of 3-tank lengths of the hull structure. The finite element (FE) model follows the modeling procedures described in Reference [7.1]. The purpose of the 3-D analysis was to determine the structural response of the hull structure for the prescribed sea loadings, and to assess the structural adequacy of hull plating of deck, bottom, sideshell, longitudinal bulkheads, and transverse bulkheads.

The extent of this FE model includes No. 2 to No. 4 tanks, both center and wing tanks. The model extends two frames fore and aft of the two end bulkheads at Frames 51 and 81. The No. 3 tanks, which may have suffered the severest damage in the casualty, are located in the center of the FE model shown in Figure 7.1.

All primary load-carrying members are modeled to ensure that the model's moment of inertia and section modulus reflect the ship's actual values. Secondary structural members that may affect overall load distribution are also included. Bending plate elements are used in the model to represent
longitudinal hull girder plating, transverse webs, transverse bulkheads, horizontal girders and stringers, and large brackets. Deck, side, bottom and bulkhead longitudinal stiffeners, and faceplates on transverse webs are modeled using beam elements. Secondary stiffening members such as panel breakers are not included in this 3D global model. The basic mesh size on transverse sections of the model is based on the spacing of the longitudinal stiffeners. A node is placed at each longitudinal location. Between transverse frames, all longitudinal plating (deck, bottom, etc.) is divided into four subdivisions to ensure reasonable aspect ratio of elements. Structural scantlings are based on the gauging report of May 2001. Since the thickness measurements are reported only at certain frames, the thicknesses measured at Frames 60, 67 and 72 were used throughout the length of Nos. 4, 3 and 2 tanks, respectively. The 3-tank length model was supported at each end of the FE model, Frames 49 and 83.

### 7.3 Loads for FE analysis

The static hull girder loads are based on the cargo loading condition during the last voyage summarized in Section 4. In view of the variations in wave-induced loads, five load cases were selected. The required loads, both the hull girder loads and local pressure loads, are defined for each load case. The selection of these loading cases takes into account the possible variations of the environmental conditions, dynamic responses, and phase relation of various load components. In determining the load combination, emphasis is given to selecting the loading pattern that would maximize local load effects.

The five load cases are listed in Table 7.1. Each of the five load cases contains a "dominant load component" at its maximum value. These maximum values of the dominant load components, such as vertical bending moment amidships, are based on the results of ship motion analyses summarized in Table 6.1. The remaining load components are the corresponding values derived from the seakeeping analysis to yield the maximum combined effects for the portion of structure considered. The combined loads from the primary hull-girder load and local loads are provided for each load case to assess yielding, buckling and ultimate strength of the structures.

- The load case 1 maximizes the sagging bending moment in head sea.
- The load case 2 maximizes the hogging bending moment in head sea.
- The load case 3 maximizes external pressures on side hull structures in head sea.
- The load case 4 represents the ship in beam sea condition. This load case maximizes external pressures.
- The load case 5 represents the ship in bow quartering sea. This load case maximizes the horizontal bending moment and horizontal shear force.

Table 7.1 Load cases for FE analysis and the dynamic load components
7.4 Structural response in seaway

Figure 7.2 shows the hull deflection and stresses for load case 1. This figure shows the full length FE structural response of the model in Figure 7.1. Maximum stresses for major structural members are summarized in Tables 7.2a to 7.2e. Both the maximum tension (denoted as "+") and compression (denoted as "-"") stresses are listed. The PRESTIGE was built of mild steel, with a minimum yielding stress of 2400 kg/cm². Most of these major structural components at the time of the casualty showed Von Mises stresses well below the material’s yielding stress (less than 50 percent yield stress for most regions of the hull). The von Mises stress is defined as

\[ \sigma_{HVM} = \sqrt{\sigma_X^2 + \sigma_Y^2 + 3 \tau_{XY}^2} \]

are the normal stresses in two coordinate directions, and in-plane shearing stress, respectively. The von Mises stresses are a specific combination of stress components, and are more relevant for representing the maximum total stresses in structures.

The hull would not have failed due to material yielding. Buckling failure is not likely to occur either considering this load level and the structural scantlings. As usually occurs in these analyses, local areas of the faceplates on some transverse web frames have calculated stresses slightly higher than the yielding stress. These areas are very local, and are unlikely to produce any problem to the transverse webs.
Table 7.2c Maximum stresses for side shell (stresses in kg/cm²)

<table>
<thead>
<tr>
<th>LC</th>
<th>Principal stress</th>
<th>Shear stress</th>
<th>Von Mises stress</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.3 Tk.</td>
<td>No.2 aft Tk.</td>
<td>No.3 Tk.</td>
</tr>
<tr>
<td>1</td>
<td>-508 / 660</td>
<td>-687 / 717</td>
<td>422</td>
</tr>
<tr>
<td>2</td>
<td>-730 / 985</td>
<td>-858 / 833</td>
<td>484</td>
</tr>
<tr>
<td>3</td>
<td>-711 / 822</td>
<td>-887 / 792</td>
<td>514</td>
</tr>
<tr>
<td>4</td>
<td>-694 / 650</td>
<td>-969 / 654</td>
<td>476</td>
</tr>
<tr>
<td>5</td>
<td>-955 / 1045</td>
<td>-1036 / 892</td>
<td>505</td>
</tr>
</tbody>
</table>

Table 7.2d Maximum stresses for longitudinal bulkhead (stresses in kg/cm²)

<table>
<thead>
<tr>
<th>LC</th>
<th>Principal stress</th>
<th>Shear stress</th>
<th>Von Mises stress</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.3 Tk.</td>
<td>No.2 aft Tk.</td>
<td>No.3 Tk.</td>
</tr>
<tr>
<td>1</td>
<td>-550 / 751</td>
<td>-794 / 869</td>
<td>416</td>
</tr>
<tr>
<td>2</td>
<td>-791 / 1007</td>
<td>-821 / 950</td>
<td>485</td>
</tr>
<tr>
<td>3</td>
<td>-689 / 815</td>
<td>-1076 / 992</td>
<td>590</td>
</tr>
<tr>
<td>4</td>
<td>-577 / 625</td>
<td>-989 / 936</td>
<td>534</td>
</tr>
<tr>
<td>5</td>
<td>-641 / 812</td>
<td>-1021 / 784</td>
<td>508</td>
</tr>
</tbody>
</table>

Table 7.2e Maximum stresses for transverse bulkhead at Frame 71 (stresses in kg/cm²)

<table>
<thead>
<tr>
<th>LC</th>
<th>Principal stress</th>
<th>Shear stress</th>
<th>Von Mises stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-783 / 1133</td>
<td>748</td>
<td>1310</td>
</tr>
<tr>
<td>2</td>
<td>-1191 / 950</td>
<td>604</td>
<td>1190</td>
</tr>
<tr>
<td>3</td>
<td>-1656 / 781</td>
<td>875</td>
<td>1680</td>
</tr>
<tr>
<td>4</td>
<td>-2006 / 808</td>
<td>1116</td>
<td>2030</td>
</tr>
<tr>
<td>5</td>
<td>-1635 / 808</td>
<td>904</td>
<td>1694</td>
</tr>
</tbody>
</table>

7.5 Influences of corrosion wastage from May 2001 to November 2002

In the finite element analysis, the structural condition is based on the May 2001 gauging report. In the analysis, no further corrosion wastage was assumed to have occurred from May 2001 to November 2002, a period of about one-and-a-half years. To evaluate the possible sensitivity of the structural strength to further corrosion during this period, the following evaluation was performed:
Under normal situations, the rate of general corrosion in oil tankers is usually very low for a period of one-and-a-half years. Seldom is the corrosion wastage more than 1 mm, though there are cases where accelerated corrosion has been reported [7.2]. Assuming structural members everywhere in the hull experienced 1 mm corrosion wastage (which is less than 5 percent wastage from the May 2001 gauging result) the vessel would have lost about 5 percent in hull girder section modulus. Even with this wastage assumption, the stresses in the hull structure are still well below the steel material’s yielding strength.

7.6 Summary
Finite element analysis of the as-gauged hull reveals that under the action of the static and dynamic loads predicted for 13 November 2002, the stresses in the major structural members are well below the yielding and buckling strength. Additional wastage due to general corrosion that may have occurred from May 2001 to November 2002 under normal conditions would not likely cause any significant increase in stresses.

References

8. FATIGUE ANALYSIS
A fatigue analysis was performed to assess the fatigue life of structural details. The most common fatigue cracking occurs at the connection of longitudinal plate stiffeners with transverse webs (Fig. 8.1). Fatigue analysis has been carried out for these connections at the transverse webs and bulkheads in tanks Nos. 2 and 3.
Figure 8.1 Typical cracking at the longitudinal connection with transverse webs [8.1]

8.1 ABS SafeHull approach to fatigue

A fatigue assessment was carried out using the ABS SafeHull analysis software. The fatigue strength data, or S-N curves, is based on U.K. Department of Energy S-N curves. These S-N curves offer better coverage of the high cycle (lower stress) regime of interest to ships and offshore structures, and have broad acceptance worldwide. The fatigue requirements are expressed in terms of permissible stress range, which are the equivalent of the allowable fatigue damage determined by a full-fledged spectral fatigue analysis. The fatigue analysis method accounts for the expected statistical distribution of stress range over time, the mathematical description of the S-N curves, the applicability of the Palmgren-Miner's Rule, and a target value of the fatigue life. The assumption made in this method is that the stress range long-term distribution follows a Weibull distribution. Thus, if one knows the extreme stress range in the target life, the characterizing Weibull distribution shape factor can be used with other known information to produce a controlling fatigue design parameter, such as allowable stress range, fatigue life in time, or fatigue damage ratio.

In the case of a complex stress field (i.e. a stress field induced by more than one type of local stress component), the procedure for combining the various load cases and detailed information for calculating the total stress ranges is given. Additionally, factors to account for stress concentrations, where
applicable, and factors to incorporate the torsional-flexural effect into fatigue damage assessment are also provided.

Starboard side shell

Port side shell

Figure 8.2 Connections that fail the SafeHull fatigue criteria (red dot: fails at 26 years, blue dot: fails at 20 years, pink wavy lines: renewed at 4th Special Survey, black wavy lines: renewed at 5th Special Survey)

In using the SafeHull fatigue strength assessment procedure, there are two important factors that need to be determined. One is how to calculate the appropriate extreme stress range, and the second is to select the suitable S-N curve for a given structural detail. These two factors are, however, interrelated. Standardized S-N curves are meant to be used in conjunction with nominal stresses in a structural component away from a localized area of stress concentration. Highly local stress concentrations, such as those produced by the presence of a weld, are already accounted for in the S-N curves. However, global or geometric stress concentrations, which could alter the nominal stress in the member, have to be separately obtained and used to modify the nominal stress. In this respect, an approximate method has
been developed for computing the nominal stress of the longitudinal stiffeners, using a "beam-column" idealization, subjected to axial load due to hull-girder effects and bending as a beam from local pressure loadings applied at the location to which the stiffener is attached. Procedures for obtaining the global or geometrical effects on the stress concentration and the associated S-N curve to be employed are also provided.

The load cases used in the SafeHull fatigue assessment are nominal design cases that are selected to maximize the notional fatigue damage. The S-N (fatigue strength) data are design curves that contain a substantial factor of safety. The long-term environmental data reflects the vessel operating 20 years in the North Atlantic, a condition that is more severe than the trading patterns of most tankers. These factors clearly tend to produce results with a conservative bias. The SafeHull fatigue strength assessment procedure takes into account corrosion wastage under normal conditions. The stress ranges for longitudinal connections with transverse webs and bulkheads are adjusted to reflect the effects of mean corrosion wastage expected for a specified design life, usually 20 years fatigue life in the North Atlantic environment.

**8.2 Results of fatigue analysis**

SafeHull has a built-in module to analyze the fatigue life of a longitudinal connection to a transverse bulkhead or transverse web. The SafeHull fatigue analysis results based on the as-built scantlings are summarized in Table 8.1. Corrosion wastage under normal conditions is considered. The local stress ranges are adjusted to reflect the effects of mean corrosion wastage. Figure 8.2 illustrates the location of connections that do not meet the SafeHull 20 year fatigue life criteria. Results are also shown for 26 year fatigue life since the *PRESTIGE* was 26 years old.

Insofar as wave-induced dynamic loads are concerned, this type of fatigue assessment can be overly conservative for the purpose intended here, as explained previously. However, notwithstanding this conservatism the results do provide, in a useful relative sense, the expected fatigue performance of the many important connection details. It is noted that the lowest fatigue life predictions are confined to a narrow portion of the suspect structure, and would not be expected to lead to the wide spread failure reportedly entailed in the casualty. The fact that there was no evidence of fatigue cracks at these connections during the last special survey in May 2001 attests to its sufficiency.
El buque estaba excedido un 63% si se consideraba la estructura sin daños y flotando en aguas calmas.

Evidentemente los daños incrementaban dichos valores de cálculo.

En dicha condición la estructura del casco estaba sometida a una severa sobrecarga, y a menos que fuera llevado rápidamente a una zona de aguas calmas, la carga adicional generada por el oleaje iría produciendo un deterioro progresivo a la misma hasta alcanzar la falla que realmente ocurrió seis días después de la primera avería.

Causas del accidente:

Aquí debemos escuchar diferentes opiniones, que lógicamente difieren sustancialmente unas de otras.
Son varios los involucrados:
   a) El país de bandera (Bahamas)
   b) La sociedad clasificadora (ABS)
   c) Las autoridades españolas, (en especial la Capitanía del puerto de Vigo).
   d) Las empresas que pueden obtener beneficios con el accidente.

a) El estado de bandera ha iniciado una profunda investigación para determinar, si es posible, la causa fundamental del accidente.
b) ABS ha analizado todos los archivos y requerido la información técnica en poder de la Autoridad Marítima de Bahamas, ofreciéndole toda la asistencia técnica necesaria para la investigación. Además está llevando a cabo un análisis detallado de las cargas dinámicas generadas por el oleaje para determinar cuales fueron las tensiones soportadas por el casco en las condiciones de daños que tenía y la inundación que había sufrido en sus tanques.

c) Las autoridades de Vigo cargan también con una gran responsabilidad al no haber permitido navegar el buque hasta una zona de aguas protegidas, y haber hecho lastrar los tanques 2 y 3 de babor para disminuir su escora.

Características del fuel de carga, comparada con el cargamento de otros buques tanques que causaron importantes derrames (información suministrada por
Figure 7.2 Stress contour and hull deflection for load case 1: the stresses in No. 3 tanks are low (No. 2 Tanks at right)

<table>
<thead>
<tr>
<th>Frame</th>
<th>Location (m) from midship</th>
<th>Case 1 (Just prior to casualty) (tonne)</th>
<th>% allow.</th>
<th>Case 2 (Flooded) (tonne)</th>
<th>% allow.</th>
<th>Case 3 (Counter-flooded) (tonne)</th>
<th>% allow.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fr 51 (BHD)</td>
<td>69.6 Aft</td>
<td>-4150</td>
<td>56%</td>
<td>-6,610</td>
<td>90%</td>
<td>-6,838</td>
<td>93%</td>
</tr>
<tr>
<td>Fr 56</td>
<td>48.55 Aft</td>
<td>364</td>
<td>5%</td>
<td>-2,968</td>
<td>39%</td>
<td>-4,045</td>
<td>53%</td>
</tr>
<tr>
<td>Fr 61 (BHD)</td>
<td>27.45 Aft</td>
<td>4806</td>
<td>58%</td>
<td>594</td>
<td>7%</td>
<td>-1,379</td>
<td>17%</td>
</tr>
<tr>
<td>Fr 66</td>
<td>6.35 Aft</td>
<td>1948</td>
<td>22%</td>
<td>630</td>
<td>7%</td>
<td>23</td>
<td>0%</td>
</tr>
<tr>
<td>Midship</td>
<td>0</td>
<td>1042</td>
<td>12%</td>
<td>601</td>
<td>7%</td>
<td>419</td>
<td>5%</td>
</tr>
<tr>
<td>Fr 71 (BHD)</td>
<td>14.75 Fwd</td>
<td>-1098</td>
<td>13%</td>
<td>486</td>
<td>6%</td>
<td>1,306</td>
<td>15%</td>
</tr>
<tr>
<td>Fr 76 (BHD)</td>
<td>35.85 Fwd</td>
<td>-4262</td>
<td>52%</td>
<td>113</td>
<td>2%</td>
<td>2,160</td>
<td>34%</td>
</tr>
<tr>
<td>Fr 81 (BHD)</td>
<td>56.95 Fwd</td>
<td>-379</td>
<td>5%</td>
<td>3,863</td>
<td>42%</td>
<td>3,756</td>
<td>51%</td>
</tr>
<tr>
<td>Fr 86</td>
<td>78.65 Fwd</td>
<td>977</td>
<td>12%</td>
<td>3,336</td>
<td>41%</td>
<td>3,421</td>
<td>42%</td>
</tr>
<tr>
<td>Fr 91 (BHD)</td>
<td>99.15 Fwd</td>
<td>1810</td>
<td>21%</td>
<td>2,996</td>
<td>34%</td>
<td>2,692</td>
<td>31%</td>
</tr>
</tbody>
</table>

5. WEATHER CONDITIONS AT THE TIME OF THE CASUALTY

The sea conditions at the time of the casualty are estimated based on two sources:

- Crew’s statement and press reports of log book information
- News reports

According to the Spanish National Institute of Meteorology, the weather on 13 November 2002 at the location of the vessel had reached force 8 at the time of the casualty. This is equivalent to severe weather with wind speeds between 62 and 74 km/h, and seas with significant wave height of 7.5 meters. The 7.5 m wave height was used in the ship motions and wave loading analysis described later in this report.