2020

Guidelines for Safety Margin of Cargo Containment System

GL-0014-E

KR

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APPLICATION OF
"Guidelines for Safety Margin of Cargo Containment System"

1. Unless expressly specified otherwise, the requirements in the Guidelines apply to ships for which contracts for construction are signed on or after 1st, September, 2020.

Effective Date 1 September. 2020

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Chapter 1. General

Section 1. Application

101. Application

This Guidelines regulates the safety margin of each cargo containment system for the ultimate, accidental and fatigue design conditions.

102. Application of design conditions

The cargo containment system structural strength shall be assessed against failure modes, including but not limited to plastic deformation, buckling and fatigue. Cargo containment systems shall be designed with safety margins as following three design conditions:

(1) to withstand ultimate design conditions for full and partial loading under the all functional and environmental conditions considering static loads, sloshing, thermal effect and hull's behaviour according to **411** and **418.1, Sec 4, Ch 5, Rules Pt 7,**

(2) to withstand accidental conditions for collision and flooding causing buoyancy on tank according to **415** and **418.3, Sec 4, Ch 5, Rules Pt 7** and

(3) to survive fatigue design conditions - the cargo containment system structure and its structural components shall not fail under accumulated cyclic loading according to **418.2, Sec 4, Ch 5, Rules Pt 7.**

103. Uncertainties in loads

Uncertain loads are mainly environmental loads in comparison with permanent load(ex: gravity) and functional loads(ex: pressure, thermally induced load, cargo weight and installation load, etc). The governing load in environmental loads is sloshing load due to ship motion and accelerations based on North Atlantic environmental conditions and relevant long-term sea state scatter diagrams for unrestricted navigation. When lesser or greater environmental conditions than North Atlantic environment is required, *a* or *b* load combination factor defined in **605.(2), Sec 6, Ch 2** in this **Guidelines** can be applied as safety margin of loads.

104. Structural model and criteria

(1) Finite element model

The structural model using a finite element model shall have relevant element density for that the structural response is well confined within the interior of the model. The structural analysis shall be carried out in accordance with **417, Sec 4 Ch 5, Rules Pt 7**

(2) Yielding criteria

Safety margin for ultimate and accidental design conditions shall be defined based on R_e and R_m as below;

R_e : specified minimum yield stress at room temperature (N/mm^2).
R_m: specified minimum tensile strength at room temperature (N/mm^2).

(3) Fatigue damage criteria

The cumulative fatigue damage shall be calculated for low cyclic load(ex: loading and unloading) and for high cyclic load(ex: wave encounters in North-Atlantic sea, not less than 10^8). Safety margin for fatigue design conditions shall be defined based on C_W define as below;

$$\sum \frac{n_i}{N_i} + \frac{n_{Loading}}{N_{Loading}} \le C_W$$

where:

n_i : number of stress cycles at each stress level during the life of the tank;

N_i : number of cycles to fracture for the respective stress level according to S-N curve;

$n_{Loading}$: number of loading and unloading cycles during the life of the tank, not to be less than 1000 for 20 years and 2000 for 40 years. Loading and unloading cycles include a complete pressure and thermal cycle;

$N_{Loading}$: number of cycles to fracture for the fatigue loads due to loading and unloading; and

C_W : maximum allowable cumulative fatigue damage ratio.

105. Corrosion allowances

Except for tanks carrying cargoes containing considerable amounts of impurities or corrosive substances such as chlorine and sulfur dioxide, no corrosion allowance may be required for aluminum alloys and stainless steel. The pressure vessels in independent tanks type C shall have corrosion allowance described in 423.2.(1), Sec 4, Ch 5, Rules Pt 7. Where the piping system in cargo containment system is constructed by carbon-manganese steel, corrosion allowance shall be applied according to 511. Sec 5, Ch 5, Rules Pt 7.

106. Thermal Effects

(1) Thermal insulation

Thermal insulation shall be provided, as required, to protect the hull from temperatures below those allowable temperature (see 419.1 Sec 4, Ch 5, Rules Pt 7) and limit the heat flux into the tank to the levels that can be maintained by the pressure and temperature control system applied in Sec 7, Ch 5, Rules Pt 7.

(2) Thermally induced loads

Transient thermally induced loads during cooling down periods shall be considered for tanks intended for cargo temperatures below -55°C. Stationary thermally induced loads shall be considered for cargo containment systems where the design supporting arrangements or attachments and operating temperature may give rise to significant thermal stresses (see 702. Sec 7, Ch 5, Rules Pt 7).

107. Material for ageing and variability

Material properties shall be certificated by Society through the material experiments based on the procedure of 419, Sec 4 Ch 5, Rules Pt 7 and international standard. Test items for insulation materials relating international standard is shown Table 7.5.4, Ch 5, Guidance Pt 7. For ageing of material, testing for thermal conductivity of thermal insulation shall be carried out on suitably aged samples.

108. Construction tolerance

Metallic materials shall be satisfied for tensile, toughness and bend test requirements and the construction requirements under design temperature defined in 603. and 604. Sec 6, Ch 5, Rules Pt 7. Inspection and non-destructive testing of welds shall be in accordance with the requirements of 605. Sec 6, Ch 5, Rules Pt 7. For type C tanks and type B tanks primarily constructed of bodies of revolution, the tolerances relating to manufacture, such as out-of-roundness, local deviations from the true form, welded joints alignment and tapering of plates having different thicknesses, shall comply with standards recognized by Society. The tolerances shall also be related to initial imperfection in the buckling analysis referred to in 422 and 423. Sec 4, Ch 5, Rules Pt 7.

109. Cargo containment systems

The specific safety margins of resistance capacity for each cargo containment system are as below;

- Type A independent tank, refe to Sec 1, Ch 2,
- Type B independent tank, refe to Sec 2, Ch 2,
- Type C independent tank, refe to Sec 3, Ch 2,
- Membrane type tank, refe to Sec 4, Ch 2,
- Integral tank and semi-membrane tank, Sec 5, Ch 2,
- Noble configuration system, refe to Sec 6, Ch 2.

Chapter 2. Safety Margin

Section 1. Type A Independent Tanks

101. Allowable stress for ultimate and accidental design conditions

The allowable nominal membrane stress for primary (web frames, stringers and girders) and secondary members (stiffeners) shall not exceed a lesser of 0.75R_e or 0.37R_m for nickel steels, carbon-manganese steels, austenitic steels and aluminium alloys.

The allowable primary equivalent stresses, σ_c defined in **418.1.(4) Sec 4, Ch 5 Rules Pt 7**, shall not exceed a lesser of 0.79R_e or 0.53R_m for nickel steels and carbon-manganese steels, a lesser of 0.84R_e or 0.42R_m for austenitic steels and a lesser of 0.79R_e or 0.42R_m for aluminium alloys.

102. Buckling utilization factor for ultimate and accidental design conditions

Buckling assessment for finite element analyses of cargo tanks subject to external pressure and other loads causing compressive stresses shall be carried out in accordance with **Ch 8, Rules Pt 13**. The utilization factor for the combination of all static and dynamic loads shall be less than 0.9 for ultimate design condition and 1.0 for accidental design condition.

103. Allowable cumulative fatigue damage ratio

For type A tanks allowable cumulative fatigue damage ratio, C_W, of tanks shall be less than 1.0. For conventional proven designs, and when the cargo temperature is not lower than -55°C, fatigue analysis of cargo tanks and supports may not be considered.

Section 2. Type B Independent Tanks

201. Allowable stress for ultimate and accidental design conditions

The allowable stresses for primarily constructed of bodies of revolution shall not exceed the formular defined as below;

$$\sigma_m \leq f$$
$$\sigma_L \leq 1.5f$$
$$\sigma_b \leq 1.5F$$
$$\sigma_L + \sigma_b \leq 1.5F$$
$$\sigma_m + \sigma_b \leq 1.5F$$
$$\sigma_m + \sigma_b + \sigma_g \leq 3.0F$$
$$\sigma_L + \sigma_b + \sigma_g \leq 3.0F$$

where:

σ_m = equivalent primary general membrane stress
σ_L = equivalent primary local membrane stress
σ_b = equivalent primary bending stress
σ_g = equivalent secondary stress;
f = the lesser of R_m/A or R_e/B; and

F = the lesser of R_m/C or R_e/D

With regard to the stresses σ_m, σ_L, σ_b and σ_g, the definition of stress categories in **428. 3, Sec 4, Ch 5, Rule Pt 7** are referred. The values A, B, C and D shall be shown on the **IGC Certificate** and shall have at least the minimum values of below table;

Values of A, B, C and D

	Nickel steels and carbon-manganese steels	Austenitic steels	Aluminium alloys
A	3	3.5	4
B	2	1.6	1.5
C	3	3	3
D	1.5	1.5	1.5
The above figures may be altered, taking into account the design condition considered in acceptance with the Society.			

The allowable membrane equivalent stresses for primarily constructed of plane surfaces, applied for finite element analysis, shall not exceed a lesser of $0.83R_e$ or $0.5R_m$ for nickel steels and carbon-manganese steels and a lesser of $0.83R_e$ or $0.4R_m$ for austenitic steels and aluminium alloys. The thickness of the skin plate and the size of the stiffener shall not be less than those required for type A independent tanks.

202. Buckling utilization factor for ultimate and accidental design conditions

For primarily constructed of bodies of revolution, the direct analysis or equivalent international standard approved by Society shall be performed for buckling assessment. For primarily constructed of plane surfaces, buckling assessment for finite element analyses of cargo tanks subject to external pressure and other loads causing compressive stresses shall be carried out in accordance with Ch 8, Rules Pt 13. The utilization factor for the combination of all static and dynamic loads shall be less than 0.9 for ultimate design condition and 1.0 for accidental design condition.

203. Allowable cumulative fatigue damage ratio

If fatigue failures that can be detected by means of leakage detection system, allowable cumulative fatigue damage ratio, C_W, of tanks shall be less than 0.5. If the leakage detection of tank barrier cannot be assured due to defect or crack development, C_W shall be less than 0.1.

Section 3. Type C Independent Tanks

301. Allowable stress for ultimate and accidental design conditions

The allowable stresses shall not exceed the formular defined in below;

$$\sigma_m \leq f$$
$$\sigma_L \leq 1.5f$$
$$\sigma_b \leq 1.5f$$

$\sigma_L + \sigma_b \leq 1.5f$

$\sigma_m + \sigma_b \leq 1.5f$

$\sigma_m + \sigma_b + \sigma_g \leq 3.0f$

$\sigma_L + \sigma_b + \sigma_g \leq 3.0f$

Where,
With regard to the stresses σ_m, σ_L, σ_b and σ_g, Refer to 201.
f = the lesser of (R_m/A) or (R_e/B);
The values A and B shall be shown on the **IGC Certificate** and shall have at least the minimum values of below table;

Values of A and B

	Nickel steels and carbon-manganese steels	Austenitic steels	Aluminium alloys
A	3	3.5	4
B	1.5	1.5	1.5

For horizontal cylindrical tanks made of C-Mn steel supported in saddles, the equivalent stress, σ_e , in the stiffening rings shall not exceed a lesser of 0.85R_e or 0.57R_m if calculated using finite element method:

$$\sigma_e = \sqrt{(\sigma_n + \sigma_b)^2 + 3\tau^2}$$

where,
σ_n : nominal stress in the circumferential direction of the stiffening ring (N/mm^2)
σ_b : bending stress in the circumferential direction of the stiffening ring (N/mm^2)
τ : shear stress in the stiffening ring (N/mm^2)

302. Design external pressure for buckling
When external pressure can be applied, the buckling assessment for cylindrical or spherical shells based on international standard (ex: Div.1 VIII, ASME) or equivalent regulation can be approved by Society. Alternatively, if nonlinear F.E analysis(*) is applied, the formular as below shall be satisfied;

$P_c/P_e \geq 3$ for cylindrical and spherical shells

where:
P_c : collapse external pressure
P_e : design external pressure defined in 423.2.(3) Sec 4, Ch 5, Rules Pt 7
Note (*) : refer to Ch 2 in "Guidelines for Ultimate Hull Girder Strength Assessment" or "Guidelines for Buckling and Ultimate Strength Assessment using Nonlinear FEA"

303. Allowable cumulative fatigue damage ratio
If fatigue failures that can be detected by means of leakage detection system, allowable cumulative fatigue damage ratio, C_W, of tanks shall be less than 0.5. If the leakage detection of tank barrier

cannot be assured due to defect or crack development, C_W shall be less than 0.1.

Section 4. Membrane Type Tanks

401. Genreal

For ultimate and accidental design conditions, the acceptance criteria of membrane tanks may be different according to kind of membrane type and can be provided by membrane tank designer and manufacturer.

402. Allowable stress and buckling pressure of membrane systems

Sloshing load due to ship motion is governing factor in comparison with other loads such as cooling-down, ship loading, vibration, static heel or collision case. In order to evaluate the structural strength of membrane, PUF, plywood and mastic in cargo containment system against sloshing load for ultimate and accidental design conditions, the following criteria is recommended.

- allowable equivalent stress : $\sigma_{eq} \le 0.67 R_e$
- allowable buckling pressure : $P_c < 0.9 P_{cr}$

P_{cr} is the critical buckling pressure which should be based on the acknowledged experimental data for each material and the standard recognized by the Society

403. Allowable stress and buckling utilization factor of pump tower

The allowable stress and buckling utilization factor from FE analysis for tubular members in the pump tower shall be applied as below

- allowable axial tensile stress : $\sigma_t \le 0.9 R_e$

- allowable axial compressive stress :

$$\sigma_c \le 0.783\,\sigma_{cr}, \qquad \text{for } \sigma_{el} \le R_e$$

$$\sigma_c \le \left(0.9 - 0.0827\sqrt{\frac{R_e}{\sigma_{el}}}\right)\sigma_{cr}, \qquad \text{for } \sigma_{el} > R_e$$

where,

σ_{el} : elastic buckling stress for tubular section (N/mm^2)

σ_{cr} : critical buckling stress for stainless steels (N/mm^2)

σ_{el} and σ_{cr} is defined in 301, Sec 3, Ch 3, Guidance for Structural Strength Assessment of Pump Tower of LNG Carriers.

- allowable shear stress : $\tau_c \le 0.52 R_e$

- allowable bending stress : $\sigma_b \le 0.9\,\sigma_{b-cr}$

σ_{b-cr} = bending strength (N/mm^2) in Guidance for Structural Strength Assessment of Pump Tower of LNG Carriers.

- acceptance criteria for axial tension and bending :

$$\left(\frac{\sigma_t}{0.9R_e}\right)+\left(\frac{\sigma_b}{0.9\,\sigma_{b-cr}}\right)\le 1$$

- acceptance criteria for axial compression and bending :

$$\left(\frac{\sigma_c}{0.783\,\sigma_{cr}}\right)+\left[\frac{\min\left(0.85,\ 1-0.4\dfrac{\sigma_c}{0.783\,\sigma_{el}}\right)\sigma_b}{\left\{0.9\,\sigma_{b-cr}\left(1-\dfrac{\sigma_c}{0.783\,\sigma_{el}}\right)\right\}}\right]\le 1,\qquad \text{for } \frac{\sigma_c}{\sigma_{cr}}>0.15$$

$$\left(\frac{\sigma_c}{0.783\,\sigma_{cr}}\right)+\left(\frac{\sigma_b}{0.9\,\sigma_{b-cr}}\right)\le 1,\qquad \text{for } \frac{\sigma_c}{\sigma_{cr}}\le 0.15$$

- allowable stress due to local buckling :

$$\sigma_c+\sigma_b\le 0.75\,\sigma_{l-cr}\ ,\qquad \text{for } \sigma_{l-cr}\le 0.55\,R_e$$

$$\sigma_c+\sigma_b\le \min\left(0.566+0.334\frac{\sigma_{l-cr}}{R_e},\ 0.9\right)\sigma_{l-cr}\ ,\qquad \text{for } \sigma_{l-cr}>0.55\,R_e$$

where,

σ_{l-cr} : critical local buckling stress (N/mm^2) in 301, Sec 3, Ch 3, Guidance for Structural Strength Assessment of Pump Tower of LNG Carriers.

404. Allowable stress of tubular joints in pump tower

The assessment of tubular joints is to be evaluated in consideration of bending, punching shear and axial stress. The tubular joints shall satisfy following formular;

$$\left|\frac{F_A}{\mu F_{UA}}\right|+\left(\frac{M_{IPB}}{\mu M_{UIPB}}\right)^2+\left|\frac{M_{OPB}}{\mu M_{UOPB}}\right|\le 1$$

Where.

μ : 0.9, safety factor

F_A : axial load in the brace member (N)

F_{UA} : tubular joint strength for brace axial load (N)

M_{IPB} : in-plane bending moment in the brace member (N-mm)

M_{UIPB} : tubular joint strength for brace in-plane bending moment (N-mm)

M_{OPB} : out-of-plane bending moment in the brace member (N-mm)

M_{UOPB} : tubular joint strength for brace out-of-plane bending moment (N-mm)

405. Allowable stress of liquid dome cover and base plate

The allowable equivalent stresses from FE analysis for liquid dome cover and base plate structure is to comply with $\sigma_{eq}\le 0.85R_e$.

406. Allowable cumulative fatigue damage ratio

If fatigue failures that can be detected by means of leakage detection system, allowable cumulative fatigue damage ratio, C_W, of liquid dome cover and bottom plate shall be less than 0.5. If the leakage detection of membrane and tubular section members in pump tower cannot be assured due to defect or crack development, C_W shall be less than 0.1.

Section 5. Integral tank and semi-membrane tanks

501. General

In the case that the ratio of design load to the structural strength of cargo containment system is less than the utilization factor selected appropriately, the cargo containment system can be approved. In order to evaluate the structural strength of cargo containment system, the analysis should be performed based on the criteria provide by designer who is responsible for the selection of criteria.

Section 6. Cargo containment system of noble configuration

601. General

The procedure and relevant design parameters of the limit state design shall comply with the standards for the use of limit state methodologies in the design of cargo containment systems of novel configuration, refer to IGC Code Appendix 5.

602. Limit states

The limit states are divided into the three following categories:

- Ultimate limit states (ULS), which correspond to the maximum load-carrying capacity or, in some cases, to the maximum applicable strain, deformation or instability in structure resulting from buckling and plastic collapse - under intact (undamaged) conditions.
- Fatigue limit states (FLS), which correspond to degradation due to the effect of cyclic loading, and:
- Accident limit states (ALS), which concern the ability of the structure to resist accident situations. (IGC Code Appendix 5, 1.)

603. Design format

The design format is based on a load and resistance factor design format. The fundamental principle of the load and resistance factor design format shall verify that design load effects do not exceed design resistances for any of the considered failure modes in any scenario.

$$L_d \le R_d$$

L_d : design load effect (e.g., stresses, strains, displacements and vibrations) which s the most unfavourable combined load effect derived from the design loads.

$$L_d = q(F_{d1}, F_{d2}, ,,, F_{dk})$$

where,

q : the functional relationship between load and load effect determined by structural analyses.

F_{dk} : design load, $F_{dk} = \gamma_f F_k$

γ_f : load factor, and

F_k : the characteristic load as specified in Sec 4, Ch 5, Rules Pt 7.

R_d : design resistance

$$R_d = \frac{R_k}{\gamma_R \gamma_C}$$

where,

R_k : the characteristic resistance. In case of materials covered by Sec 6, Ch 5, Rules Pt 7, it may be, but not limited to, specified minimum yield stress, specified minimum tensile strength, plastic resistance of cross sections, and ultimate buckling strength.

γ_R : the resistance factor, defined as $\gamma_R = \gamma_m \gamma_s$.

γ_m : the partial resistance factor to take account of the probabilistic distribution of the material properties (material factor).

γ_s : the partial resistance factor to take account of the uncertainties on the capacity of the structure, such as the quality of the construction, method considered for determination of the capacity including accuracy of analysis.

γ_C : the consequence class factor, which accounts for the potential results of failure with regard to release of cargo and possible human injury. γ_C is divided into three levels as below;

- low : failure implies minor release of the cargo
- medium : failure implies release of the cargo and potential for human injury
- high : failure implies significant release of the cargo and high potential for human injury/fatality.

(IGC Code Appendix 5, 2.)

604. Finite element analysis

Three dimensional finite element analyses shall be carried out as an integrated model of the tank and the ship hull, including supports and keying system as applicable. All the failure modes shall be identified to avoid unexpected failures. Hydrodynamic analyses shall be carried out to determine the particular ship accelerations and motions in irregular waves and the response of the ship and its cargo containment systems to these forces and motions. Analysis requirements are as below;

- Buckling strength analyses of cargo tanks subject to external pressure and other loads causing compressive stresses shall be carried out in accordance with Ch 8, Rules Pt.13 or equivalent. The method shall adequately account for the difference in theoretical and actual buckling stress as a result of plate out of flatness, plate edge misalignment, straightness, ovality and deviation from true circular form over a specified arc or chord length, as relevant.
- Fatigue and crack propagation analysis shall be carried out in accordance with (6) to (9), 418.2, Sec 4, Ch 5, Rules Pt 7.

(IGC Code Appendix 5, 3.)

605. Ultimate limit state

(1) Determination of Structural resistance

Structural resistance may be established by testing or by complete analysis taking account of both elastic and plastic material properties. Safety margins for ultimate strength shall be introduced by partial factors of safety taking account of the contribution of stochastic nature of loads and resistance considering dynamic loads, pressure loads, gravity loads, material strength, and buckling capacities.

(IGC Code Appendix 5 4.1)

(2) Load combination factor

Appropriate combinations of permanent loads, functional loads and environmental loads including sloshing loads shall be considered in the analysis. At least two load combinations with partial load factors as given in below Table shall be used for the assessment of the ultimate limit states.

Load combination	Permanent loads	Functional loads	Environmental loads
a	1.1	1.1	0.7
b	1.0	1.0	1.3

The load factors for permanent and functional loads in load combination *a* are relevant for the normally well controlled and/or specified loads applicable to cargo containment systems such as vapour pressure, cargo weight, system self-weight, etc. Higher load factors may be relevant for permanent and functional loads where the inherent variability and/or uncertainties in the prediction models are higher. (IGC Code Appendix 5 4.2)

(3) Load factors for sloshing

For sloshing loads, depending on the reliability of the estimation method, a larger load factor may be required by the Society. (IGC Code Appendix 5 4.3)

(4) Consequence class factor

In cases where structural failure of the cargo containment system are considered to imply high potential for human injury and significant release of cargo, the consequence class factor shall be taken as $\gamma_C = 1.2$. This value may be reduced if it is justified through risk analysis and subject to the approval by the Society. The risk analysis shall take account of factors including, but not limited to, provision of full or partial secondary barrier to protect hull structure from the leakage and less hazards associated with intended cargo. Conversely, higher values may be fixed by the Society, for example, for ships carrying more hazardous or higher pressure cargo. The consequence class factor shall in any case not be less than 1.0.
(IGC Code Appendix 5 4.4)

(5) Safety level equivalence

The load factors and the resistance factors used shall be such that the level of safety is equivalent to that of the cargo containment systems as described in 2. through 6. This may be carried out by calibrating the factors against known successful designs.
(IGC Code Appendix 5 4.5)

(6) Material factors

The material factor γ_m shall in general reflect the statistical distribution of the mechanical properties of the material, and needs to be interpreted in combination with the specified characteristic mechanical properties. For the materials defined in Sec 6, Ch 5, Rules Pt 7, the material factor γ_m may be taken as:

1.1 : when the characteristic mechanical properties specified by the Society typically represents the lower 2.5% quantile in the statistical distribution of the mechanical properties, or

1.0 : when the characteristic mechanical properties specified by the Society represents a sufficiently small quantile such that the probability of lower mechanical properties than specified is extremely low and can be neglected.

(IGC Code Appendix 5 4.6)

(7) Resistance factors

The partial resistance factors γ_s shall in general be established based on the uncertainties in the capacity of the structure considering construction tolerances, quality of construction, the accuracy of the analysis method applied, etc.

(IGC Code Appendix 5 4.7)

(8) Resistance factors for plastic deformation

For design against excessive plastic deformation using the limit state criteria, the partial resistance factors γ_s shall be taken as follows:

$$\gamma_{s1} = 0.76 \frac{B}{\min\left(\frac{R_m}{R_e}\frac{A}{B},\ 1.0\right)} \quad , \quad \gamma_{s2} = 0.76 \frac{D}{\min\left(\frac{R_m}{R_e}\frac{D}{C},\ 1.0\right)}$$

Factors A, B, C and D are defined in **201. Sec 2 Ch 2**. The partial resistance factors given above are the results of calibration to conventional type B independent tanks.

(IGC Code Appendix 5 4.7.1)

(9) Design against excessive plastic deformation

Stress acceptance criteria given below refer to elastic stress analyses (IGC Code Appendix 5 4.8.1). Parts of cargo containment systems where loads are primarily carried by membrane response in the structure shall satisfy the limit state criteria in **201. Sec 2 Ch 2**. replacing following factors; (IGC Code Appendix 5 4.8.2)

$$f = \frac{R_e}{\gamma_{s1}\gamma_m\gamma_C} \quad , \quad F = \frac{R_e}{\gamma_{s2}\gamma_m\gamma_C}$$

Parts of cargo containment systems where loads are primarily carried by bending of girders, stiffeners and plates, shall satisfy the following limit state criteria:

$$\sigma_{ms} + \sigma_{bp} \le 1.25F \quad ^{(1),(2)}$$
$$\sigma_{ms} + \sigma_{bp} + \sigma_{bs} \le 1.25F \quad ^{(1)}$$
$$\sigma_{ms} + \sigma_{bp} + \sigma_{bs} + \sigma_{bt} + \sigma_g \le 3.0F$$

(Note 1): The sum of equivalent section membrane stress and equivalent membrane stress in primary structure ($\sigma_{ms} + \sigma_{bp}$) will normally be directly available from three-dimensional finite element analyses.

(Note 2): The coefficient, 1.25, may be modified by the Society considering the design concept, configuration of the structure, and the methodology used for calculation of stresses.

where,

σ_{ms} : equivalent von Mises section membrane stress in primary structure in N/mm^2

σ_{bp} : equivalent von Mises membrane stress in primary structure and stress in secondary (stiffener) and tertiary (plating) structure caused by bending of primary structure.

σ_{bs} : equivalent von Mises section bending stress in secondary structure (stiffener) and stress in tertiary structure (plating) caused by bending of secondary structure (stiffener) in N/mm^2

σ_{bt} : equivalent von Mises section bending stress in tertiary structure, i.e. plate bending stress in N/mm^2

σ_{g} : equivalent von Mises secondary stress in N/mm^2

(IGC Code Appendix 5 4.8.3)

Normal stress is the component of stress normal to the plane of reference. Equivalent section membrane stress is the component of the normal stress that is uniformly distributed and equal to the average value of the stress across the cross section of the structure under consideration. If this is a simple shell section, the section membrane stress is identical to the membrane stress. Section bending stress is the component of the normal stress that is linearly distributed over a structural section exposed to bending action. (IGC Code Appendix 5 4.8.4)

(10) Resistance factors for buckling

The same factors γ_C , γ_m and γ_s shall be used for design against buckling unless otherwise stated in the applied recognised buckling standard. In any case the overall level of safety shall not be less than given by these factors.

606. Fatigue limit states

(1) Fatigue load factor

Fatigue design condition as described in **418.2, Sec 4, Ch 5, Rules Pt 7** shall be complied with as applicable depending on the cargo containment system concept. The load factors for FLS shall be taken as 1.0 for all load categories.

(IGC Code Appendix 5 5.2)

(2) Consequence class and resistance factor

Consequence class factor γ_C and resistance factor γ_R shall be taken as 1.0.

(IGC Code Appendix 5 5.3)

(3) Cumulative fatigue damage ratio

Fatigue damage shall be calculated as described in **1.5**. The calculated cumulative fatigue damage ratio for the cargo containment systems shall be less than or equal to the values given in below Table.

	Consequence class		
C_W	low	medium	high
	1.0	0.5	0.5 (1)
1) Lower value shall be used in accordance with **(6)~(9) 418.2, Sec 4, Ch 5 Rules Pt 7** depending on the detectability of defect or crack, etc.			

(IGC Code Appendix 5 5.4)

(4) Crack propagation analyses

Crack propagation analyses shall be carried out in accordance with methods laid down in 419.2 (6) to (9), Sec 4, Ch 5, Rules Pt 7.
(IGC Code Appendix 5 5.6)

607. Accident limit states

(1) Accident design condition shall be complied with as applicable, depending on the cargo containment system concept. (IGC Code Appendix 5 6.1)

(2) Load and resistance factors may be relaxed compared to the ultimate limit state considering that damages and deformations can be accepted as long as this does not escalate the accident scenario. (IGC Code Appendix 5 6.2)

(3) The load factors for ALS shall be taken as 1.0 for permanent loads, functional loads and environmental loads. (IGC Code Appendix 5 6.3)

(4) Loads related static heel loads, collision and loads due to flooding on ship need not be combined with each other or with environmental loads. (IGC Code Appendix 5 6.4)

(5) Resistance factor γ_R shall in general be taken as 1.0.
(IGC Code Appendix 5 6.5)

(6) Consequence class factors γ_C shall in general be taken as defined in (4), 605, but may be relaxed considering the nature of the accident scenario.
(IGC Code Appendix 5 6.6)

(7) The characteristic resistance R_k shall in general be taken as for the ultimate limit state, but may be relaxed considering the nature of the accident scenario.
(IGC Code Appendix 5 6.7)

(8) Additional relevant accident scenarios shall be determined based on a risk analysis.
(IGC Code Appendix 5 6.8)

608. Testing requirements

Cargo containment systems designed according to this Guidelines shall be tested to the same extent as described in 420, Sec 4, Ch 5, Rules Pt 7, as applicable depending on the cargo containment system concept. (IGC Code Appendix 5 7.1)

Guidelines for Safety Margin of Cargo Containment System

Published by
KR
36, Myeongji ocean city 9-ro, Gangseo-gu,
BUSAN, KOREA
TEL : +82 70 8799 7114
FAX : +82 70 8799 8999
Website : http://www.krs.co.kr