IACS Common Structural Rules for Double Hull Oil Tankers, January 2006

Background Document

SECTION 8/6 – SCANTLING REQUIREMENTS EVALUATION OF STRUCTURE FOR SLOSHING AND IMPACT LOADS

NOTE:

- This TB is published to improve the transparency of CSRs and increase the understanding of CSRs in the industry.
- The content of the TB is not to be considered as requirements.
- This TB cannot be used to avoid any requirements in CSRs, and in cases where this TB deviates from the Rules, the Rules have precedence.
- This TB provides the background for the first version (January 2006) of the CSRs, and is not subject to maintenance.

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6.1.1 Application

6.1.1.a It is considered that for this topic, no information in addition to that shown in the Rules is necessary to explain the background.

6.1.2 General scantling requirements

6.1.2.a It is considered that for this topic, no information in addition to that shown in the Rules is necessary to explain the background.

6.2 Sloshing in Tanks

6.2.1 Scope and limitations

6.2.1.a The basis for the sloshing requirements given in *Section 8/6.2 of the Rules* is taken from the January 2003 issue of DNV Rules Pt.3 Ch.1 Sec.4 C300.

6.2.1.b The objective of the sloshing requirements given in *Section 8/6.2 of the Rules* is to ensure that tanks carrying liquid have adequate strength to withstand the pressures arising due to liquid movement in partially filled tanks.

6.2.1.c In accordance with the principles and design basis of the rules all tanks are to be designed for unrestricted filling. The design basis for cargo tanks is unrestricted filling with cargo density of 1.025. In case of higher design density than 1.025 tonnes/m^3 filling restrictions may be given.

6.2.1.d Smaller tanks as mentioned in *Section 8/6.2.1.2 of the Rules* are not required to be assessed for sloshing. For such tanks the sloshing pressure is small and will not be the dimensioning criteria for the tank structure. Tanks for lubrication oil and similar located in the engine room are considered small tanks and do not require assessment for sloshing.

6.2.1.e The structural elements to be assessed for the event of sloshing are given in *Section 8/6.2.1.4 of the Rules.* Sloshing is assumed to be a local load effect and hence only local support members, e.g. plates, stiffeners on tight boundaries and web plating and web-stiffeners/tripping brackets on primary support members are required assessed based on sloshing. Sloshing pressures are most significant around the actual filling height and will not act on the entire bulkhead simultaneously. Consequently the shear and bending strength of primary support members are not required to be assessed based on sloshing loads.

6.2.1.f For tanks with effective breadth and length less than 0.56B and 0.13L respectively the high velocity impact pressure is not assumed to be governing and specific impact calculations are not required. For longer tanks such pressures might be governing for the scantlings and assessment is required in accordance with the rules of the society to which the actual vessel is under classification. See background to *Section 7/4.2.1 of the Rules* for further details.

6.2.1.g The symbols given in *Section 8/6.2.2,* are taken from the load section, *Section 7/4.2* where further details and definitions are provided.

6.2.2 Application of sloshing pressure

6.2.2.a The calculated sloshing pressures $P_{slh-lng}$ and P_{slh-t} are only governing for large open tanks. For smaller tanks and tanks with a lot of internal structure e.g. double skin tanks, the minimum sloshing pressure, $P_{slh-min}$, will be governing. Hence only large open tanks are required assessed based on the calculated pressures

6.2.2.b The cut-off values of 0.03L and 0.32B for calculation of sloshing pressures $P_{slh-lng}$ and P_{slh-t} respectively are derived from the formulas for the two sloshing pressures. For effective lengths and breadths below these limit values the sloshing formulae give pressures that are less than the minimum sloshing pressure of 12kN/m^2 and hence will not be governing.

6.2.2.c The sloshing pressure due to longitudinal liquid motion, $P_{slh-lng}$, doesn't only act on the transverse bulkheads but also the panels attached to the bulkhead, e.g. deck, longitudinal bulkheads and stringers. The reason is that pressure in liquid acts in all directions and hence the pressure will act on the neighbouring surfaces as the moving liquid hits the transverse bulkhead. The extension of this effect is limited to the smallest of 0.25 l_{slh} from the bulkhead and first transverse web frame.

6.2.2.d Similarly the sloshing pressure due to transverse liquid motion, P_{slh-t}, doesn't only act on the longitudinal bulkheads but also the panels attached to the bulkhead, e.g. deck, transverse bulkheads and girders/webframes/stringers. The reason is that pressure in liquid acts in all directions and hence the pressure will act on the neighbouring surfaces as the moving liquid hits the transverse bulkhead. The extension of this effect is limited to the smallest of 0.25 b_{slh} from the bulkhead and first longitudinal web frame/girder.

6.2.2.e Webs and stiffeners of internal transverse web frames close to (within 0.25 l_{slh}) the transverse bulkhead are required assessed for sloshing due to longitudinal liquid motion. This assessment is required in order to ensure that the web frame can withstand the pressures arising as the liquid is reflected off the transverse bulkhead.

6.2.2.f Similarly webs and stiffeners of internal longitudinal web frames close to (within 0.25 b_{slh}) longitudinal bulkhead are required assessed for sloshing due to transverse liquid motion

6.2.2.g The lower boundary/inner bottom of the tank is not evaluated for sloshing as this will not be the governing load for this structure. The lower boundary of the tank is typically governed by static and static+dynamic associated with a full tank. In order to have sloshing on the lower tank boundary the filling level in the tank will have to be very low. As the sloshing pressures reduces with reducing filling height, ref f_{slh} factor defined in *Section 7/4.2.2.1 and 4.2.3.1 of the Rules* an eventual sloshing pressure on the lower tank boundary will be small.

6.2.2.h The sloshing pressures due to longitudinal and transverse liquid motion are assumed to be independent in the sense that one is zero when the other is maximum, and vice versa. Structural elements in areas subject to both longitudinal and transverse sloshing pressure are to be evaluated based on the maximum of the two – and not the added pressure.

6.2.3 Sloshing assessment of plating forming tank boundaries

6.2.3.a The sloshing pressures given in the rules are associated with a "normal" or "typical" load level, e.g. daily maximum. The evaluation of the structure against sloshing loads is covered by *Design Load Combination 3* and *Acceptance Criteria Set AC1* as shown in *Table 2.5.1 of the Rules*. The sloshing loads, which are taken from the DNV Rules Pt.3 Ch.1 Sec.4 C300, are at a probability level of 10-4 and not 10-8 which the dynamic loads related to AC2 acceptance are. The sloshing loads in the JTP Rules are hence given as the daily maximum and are therefore characterized as being frequent loads. Consequently the acceptance criteria related to frequent acting loads, AC1, is more appropriate than AC2. The allowable stress for sloshing assessment in the existing DNV Rules is in the order of 0.67 x yield and hence similar to that of the Common Structural Rules

6.2.3.b The background for development of the formulae for required thickness is described in details in Background to *Section 8/Table 8.2.4*.

6.2.3.c Structural assessment due to sloshing is done based on combining the stresses due to sloshing pressures and the stresses due to static hull girder loads.

6.2.3.d Internal static and inertia pressures are not added as the sloshing pressure is only significant just above and below the free surface level where the mentioned other internal pressures are small. Sloshing is also an effect of the liquid moving towards a barrier while the static and inertia loads assume that the liquid remains in contact with the boundary.

6.2.3.e Hull girder dynamic stresses (hull girder wave bending) are not added as they are assumed to be small when the sloshing pressure reaches its maximum. The background is that maximum sloshing occurs in an irregular sea state where the dynamic hull girder stresses are small. The maximum dynamic hull girder stress will arise in a sea state with regular long crested waves

6.2.3.f The sloshing assessment in the Rules is based on elastic design and capacity models. The use of plastic design criteria for assessment of sloshing is typically related to the high velocity sloshing impact that may occur in large tanks. For oil tankers of standard design with tanks with limited sloshing length and breadth this phenomena is not governing and the tanks are typically assessed for quasi static loads representing liquid movement in the tanks. The same is done in the JTP Rules where the mandatory sloshing assessment is a quasi static approach based on elastic design criteria and a reference is given to each individual Classification Societies rules for assessment of high velocity impact loads for large tanks. The latter is typically related to a localised load and acceptance criteria based on plastic capacity.

6.2.4 Sloshing assessment of stiffeners on tank boundaries

6.2.4.a Background on load level, design load combination, combination of stresses is as given in *6.2.3.a* for plates on tank boundaries

6.2.4.b The background for development of the formulae for required section modulus thickness is described in details in *Background to Section 8/Table 8.2.5*.

6.2.4.c A sloshing related shear requirement for the stiffeners is not included in the Rules as this is not governing for the scantling of the stiffeners.

6.2.5 Sloshing assessment of primary support members

6.2.5.a Background on load level, design load combination, combination of stresses is as given in *6.2.3.a* for plates on tank boundaries.

6.2.5.b It should be noted that only the local elements of the primary support members are assessed for the event of sloshing as sloshing is a local phenomena. E.g. web plating between stiffeners is assessed, webstiffeners are assessed and tripping brackets supporting the web is assessed while the primary support member as a single component is not assessed for bending and shear assuming sloshing pressures on parts or all of the load area (span x load breadth). The latter is not included as the primary support members a single element will be dimensioned by the combined static and inertia loads/criteria given in *Section 8/2.6 of the Rules*.

6.3 Bottom Slamming

6.3.1 Application

6.3.1.a Definition of 0.045*L* is taken from LR Rules Pt 3, Ch 5, 1.5.1

6.3.2 Extent of strengthening

6.3.2.a Based on LR Rules Pt 3, Ch 5,1.5.4. Vertical extent of strengthening is increased to 500mm based on feedback from ships in operation damage experience.

6.3.3 Design to resist bottom slamming loads

6.3.3.a The Rule text is intended to encourage the adoption of built in end constraints in design. Where arrangements do not achieve equivalent "built in" end fixity, then correction to the scantling requirements is required.

6.3.3.b Attention is drawn to the need to ensure that the supporting structures provide an adequate load path to ensure the satisfactory transmission of load. Reference to good design practise is included.

6.3.4 Hull envelope plating

6.3.4.a The plate bending capacity model for slamming loads was developed to be consistent with the plate bending capacity model adopted elsewhere in *Section 8 of the Rules*.

6.3.4.b The coefficient C_d implies a slightly increased acceptance level of permanent set in plate panels subject to impact loads at the bow, reflecting the uncertainty of the frequency of the slamming loads. The choice of coefficients C_d and C_a assume that the only load acting on the plate panel is the slamming impact pressure, hence hull girder and other membrane stresses are neglected in the formulation. C_a is maintained to be consistent with the standard plate thickness equation used elsewhere.

6.3.4.c The value of C_d was finalised based on comparison with the existing plate bending capacity models used by in the existing slamming requirements of LR, DNV and ABS and calibration carried out on the Rule development test vessels.

6.3.5 Hull envelope stiffeners

6.3.5.a The stiffener bending capacity model was developed from an existing concept used by DNV and LR. A three hinge plastic collapse model was adopted considering the normal failure modes seen in damage case history related to bottom slamming.

6.3.5.b The capacity model features an explicit assumption of end fixity and utilisation factor of yield stress consistent with the design philosophy.

6.3.6 Definition of idealised bottom slamming load area for primary support members

6.3.6.a Concept of idealised bottom slamming load area is taken from LR direct calculation procedure. Since impact phenomena is localised, non-stationary and time dependent, the magnitude of loads acting on a structure depend on the size of the structure being considered, in relation to its response to the applied load.

6.3.6.b The extent of primary support members is assumed large in comparison to individual plating and stiffener components. Hence the average load on the primary member during a "slam" event will be lower than the pressure value assumed to act on the plating or stiffener.

6.3.7 Primary support members

6.3.7.a For double skin structures, the ultimate bending capacity of double bottom girders and floors has been shown by experience to be satisfactory, provided the scantlings of these items are derived by normal strength criteria. Hence only an explicit control for shear area of primary support members, together with appropriate buckling control is included

6.3.7.b The Rules include a simplified method of predicting the worst case load distribution. The worst case load distribution can also be derived by direct calculations.

6.3.7.c Slenderness ratio for web plate of primary support members based on LR Rule Pt 3 Ch 5,Table 5.1.1 and adjusted for the net thickness model.

6.3.8 Connection of longitudinals to primary support members

6.3.8.a End connection requirements are aligned with the requirements for end connections of *Section 4/3.2.3 of the Rules*.

6.4 Bow Impact

6.4.1 Application

6.4.1.a Definition of 0.1*L* is taken from DNV Rules Pt.3 Ch.1 Sec.7 E301.

6.4.2 Extent of strengthening

6.4.2.a It is considered that for this topic, no information in addition to that shown in the Rules is necessary to explain the background.

6.4.3 Design to resist bow impact loads

6.4.3.a The Rule text is intended to encourage the adoption of built in end constraints in design. Longitudinal/horizontal framing is particularly encouraged to be used because of the superior load response capacity of curved stiffened panels. Further, it is noted that longitudinal framing generally promotes superior structural details.

6.4.3.b Where arrangements do not achieve equivalent "built in" end fixity, then correction to the scantling requirements is required.

6.4.3.c Attention is drawn to the need to ensure that the supporting structures provide an adequate load path to ensure the satisfactory transmission of load. Reference to good design practise is included.

6.4.3.d The stiffening direction of decks and bulkheads supporting shell frames is requested to be parallel to the direction of the compressive plate stress for improved buckling capacity.

6.4.4 Side shell plating

6.4.4.a The plate bending capacity model for impact load is consistent with that adopted for slamming requirements.

6.4.4.b In case of bow impact, the co-efficient C_d is taken as one and hence not shown in the formula, reflecting the reduced tolerance of permanent set in plate panels subject to impact loads at the bow. The choice of coefficients C_d and C_a assume that the only load acting on the plate panel is the bow impact pressure, hence hull girder and other membrane stresses is neglected in the formulation. C_a is maintained to be consistent with the standard plate thickness equation used elsewhere.

6.4.4.c The value of C_d was finalised based on:

(a) Comparison with the existing plate bending capacity models used by in the existing slamming requirements of LR, DNV and ABS and calibration carried out on the Rule development test vessels.

(b) Verification by non-linear analysis.

6.4.5 Side shell stiffeners

6.4.5.a The stiffener bending capacity model is consistent with that used in slamming. A three hinge plastic collapse model was adopted considering the normal failure modes seen in damage case history related to bottom slamming.

6.4.5.b The capacity model features an explicit assumption of end fixity and utilisation factor of yield stress consistent with the design philosophy.

6.4.5.c For breast hooks/diaphragm plates a minimum thickness requirement and slenderness ratio requirement are included based on LR rules and adjusted for the net thickness model, thus addressing the most common failure mode for these structural items.

6.4.6 Definition of idealised bow impact load area for primary support members

6.4.6.a Idealised impact load area concept is aligned with that adopted for slamming scantling criteria for simplicity.

6.4.7 Primary support members

6.4.7.a Taken from DNV Rules.

6.4.7.b Minimum spacing for primary support members included in order to limit deflection of primary support members.

6.4.7.c Paragraph is intended to encourage good design details which ensure the structure is adequate for the Rule load.

6.4.7.d Paragraph is intended to encourage good design details which ensure the structure is adequate for the Rule load.

6.4.7.e The primary support member bending capacity model is in the form of applied bending moment over permissible stress. The factors f_{bdg-pt} and f_{slm} give the maximum bending resulting from the application of an idealised uniformly distributed impact load anywhere within the span length of a fixed ended beam.

6.4.7.f The primary support member shear capacity model is in the form of applied shear force divided by permissible stress. The factor f_{pt} gives the maximum shear force at the end of the shear span, resulting from the application of an idealised uniformly distributed impact load within the span length of a fixed ended beam.

6.4.7.g The minimum web thickness formulation is to ensure that the critical buckling stress of the web plating or deck/bulkhead plating in way or adjacent to the side shell exceeds the axial stress resulting from application of the idealised impact load.

6.4.8 Connection of stiffeners to primary support members

6.4.8.a End connection requirements are aligned with the requirement for end connections of *Section 4/3.2.3 of the Rules*.