GUIDANCE NOTES
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CHINA CLASSIFICATION SOCIETY

# GUIDELINES FOR UNDERWATER RADIATED NOISE OF SHIPS

# 2018

Effective from 15 Oct. 2018

**Beijing**

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# Section 1 General

## 1.1 Purpose

1.1.1 The Guidelines are intended to provide technical guidance on the design, installation, usage and maintenance of hull monitoring and assistant decision-making system for ships engaged on voyages in ice regions (hereinafter referred to as monitoring and decision system).

1.1.2 The Guidelines include the conditions and operational procedures for the monitoring and decision system. The state of hull structures is monitored, assessed and recorded through measuring and recording the structural response during operation of ships in ice.

1.1.3 The Guidelines provide technical guidance for users on selecting monitoring and decision system, setting data measurement and recording method, and determining safety threshold alarms. The Guidelines are not intended to replace the responsibilities of ship owners and equipment suppliers on the monitoring and decision system.

## 1.2 Application

1.2.1 Monitoring and decision system is to be provided with an independent start/close control function. Prior to entry of a ship into ice, the monitoring and decision system is started, and after the ship is out of ice, the system is closed.

1.2.2 During operation of a ship in ice, the monitoring and decision system can provide real time measurement information on hull structural response under the effects of ice load conditions.

1.2.3 When the real time measurement information approaches/exceeds structural safety threshold, the monitoring and decision system is to provide safety warning/alarms to ships and provide corresponding suggestions on decision making.

1.2.4 The monitoring and decision system is to be capable of predicting subsequent trend of data change based on the available measurement information. When such trend is likely to approaches safety threshold, a safety reminder is to be given to the ship.

1.2.5 When newly installed for use in the first time in ice, the monitoring and decision system is to be used in comparison with other polar risk index systems (e.g. POLARIS).

1.2.6 For accumulation of ice load data, CCS may consider, in consultation with ship owners, to add ice load inversion function in the monitoring and decision system.

## 1.3 Definitions

1.3.1 The definitions in CCS Rules for Classification of Sea-going Steel Ships, International Code for Ships Operating in Polar Waters by IMO (Polar Code), CCS Guidelines for Polar Ships and CCS Polar Water Operation Manual are applicable to the Guidelines.

1.3.2 **Monitoring and decision system** means a system that is capable of monitoring relevant parameters and judge the safety level of structural spaces through comparison with safety thresholds.

1.3.3 **Monitoring parameters** mean the data that can describe hull structural response and/or ship motion. Local stress in ice belt area under the impact of ice load is the most important parameter.

1.3.4 **Safety threshold** means the permissible stress value of a monitored node that is provided according to the rule strength criteria and the structural formation of a monitored structural member. This value is determined by the designer and can serve as the reference for decision support during operations in ice; however, it cannot replace the decision and responsibilities of the Master during operations in ice.

1.3.5 **Assessment index** means the ratio of the measured stress, after data processing, of a structural member to the safety threshold.

1.3.6 **Early warning** means an information on danger forecasting released by the monitoring and decision system when the assessment index of the monitored hull position of a ship operates in ice equals or is more than 0.8

1.3.7 **Alarm** means the information on danger released by the monitoring and decision system when the assessment index of the monitored hull position of a ship operates in ice equals or is more than 1.

1.3.8 **Safety reminder** means that the information reminding safety is to be released when the monitoring and decision system predicts that the assessment index of the monitored hull position of a ship operates in ice approaches 1.

1.3.9 **Ice class rules** mean CCS Rules for Classification of Sea-going Steel Ships, PART EIGHT, Chapter 13 Additional Requirements for Polar Class Ships, and CCS Rules for Classification of Sea-going Steel Ships, PART TWO, Chapter 4 Strengthening for Navigation in Ice.

1.3.10 **Standard ice operation mode** means an operation scenario that is assumed in the ice class rules, including operation methods, ice conditions and ship speed, etc.

1.3.11 **Non-standard ice operation mode** means an operation scenario other than the standard ice operation mode.

1.3.12 **Real time** means the actual time during ice operation.

1.3.13 **Short-term forecast** means the prediction of change within a short period.

### 1.4 Class notations

1.4.1 Ships that are installed with monitoring and decision system according to the requirements of the Guidelines and relevant rules can apply for the class notation related to the monitoring and decision system: HMS-ICE, and characters for extended operations as appropriate, such as HMS-ICE(Turn, Glancing).

1.4.2 According to the requirements of Section 2 of the Guidelines, the class notation for monitoring and decision system can be assigned to a ship with ice class which is capable of monitoring stress of structure members in ice belt area during operations in ice and can send a safety alarm when the monitored value and forecasted value approach or exceed safety value, and will provide a suggestion on modification of operation to the Master.

1.4.3 According to the relevant requirements of Section 3 of the Guidelines, ships with ice class which comply with the requirements for monitoring based on non-standard ice operation mode can be assigned with characters for extended operations as appropriate.

Table 1.4.3

| Character | Description |
|---|---|
| Turn | The monitoring and decision system that can meet the need for monitoring of structural response in ice belt area during turning of ships in ice |
| Glancing | The monitoring and decision system that can meet the need for monitoring of hull girder bending and shear during glancing operation of ships in ice |
| Oblique | The monitoring and decision system that can meet the need for monitoring of structural response in ice belt area during oblique operation of ships in ice |
| Stern-Ahead | The monitoring and decision system that can meet the need for monitoring of structural response in ice belt area during stern-ahead operation of ships in ice |
| Shallow-Water | The monitoring and decision system that can meet the need for monitoring of structural response of ship bottom during shallow-water operations of ships in ice |

1.4.4 Class notations as indicated in 1.4.2 and 1.4.3 are to be assigned according to the approved plans, equipment certificates and ship surveys.

1.4.5 The monitoring and decision system (including sensors) are to be provided with CCS type approval certificate.

**1.5 Plans and documents**

1.5.1 The following documents are to be submitted for approval:

(1) Sensor arrangement (including information on each sensor, safety threshold of monitored nodes);

(2) Electric system diagram of the monitoring and decision system.

1.5.2 The following documents are to be submitted for information:

(1) Description of related software (including data processing unit);

(2) User's manual for monitoring and decision system.

**1.6 Survey and test**

1.6.1 An initial survey is to at least include the following items:

(1) to confirm that related plans and documents have been reviewed;

(2) to confirm that the monitoring and decision system has been reflected in the polar water operational manual (PWOM);

(3) to confirm that the system and hardware products (including sensors) are provided with appropriate certificates;

(4) after installation of the equipment, to carry out survey and test according to the test procedure and calibration procedure of the monitoring device, so as to verify system function.

1.6.2 During annual survey/intermediate survey/special survey, the following items are to be inspected, so as to confirm the monitoring and decision system is in normal function:

(1) Record of maintenance of the monitoring and decision system;

(2) General performance of the monitoring and decision system;

(3) Details and cause analysis of system malfunction/failure;

(4) Repair record and replacement of spare parts;

(5) Inspection and confirmation that the apparatus and instruments in relation to the monitoring and decision system are calibrated according to the specified procedures and plans;

(6) Actual verification of some tests and analysis if deemed necessary by the surveyor.

1.6.3 In case of malfunction of the monitoring and decision system, or damage, repair and replacement of equipment, or substantial change of the means of monitoring, shipowners or ship management companies are to apply for an occasional survey.

**1.7 Documents maintained onboard**

1.7.1 The user's manual is to be kept on board, and is at least to describe the following:

(1) operation;

(2) setting and calibration of sensors and the system;

(3) failure identification;

(4) repair;

(5) system maintenance and functional tests (indicating test methods for the components and system and what is to be observed during test);

(7) explanations of test result.

1.7.2 The log on maintenance and calibration of the monitoring and decision system is to be kept on board.

## Section 2 Hull monitoring and assistant decision-making system for operations in ice

### 2.1 General

2.1.1 This section provides basic requirements for the monitoring and decision system installed on ships using standard ice operational mode.

2.1.2 The monitoring and decision system is to be able to monitor the stresses of structural members in ice belt area during operations in ice and can send a safety alarm when the monitored value and forecasted value approach or exceed safety value, and will provide a suggestion on modification of operation to the Master.

2.1.3 The measurement frequency for the monitoring and decision system is to meet the requirements for measuring impact load, recommended as not to be less than 150Hz. Zero drift during the measurement is to be eliminated, and operational measures such as using earthing wires and timely cleaning and balancing are to be adopted.

2.1.4 The wheelhouse is to indicate in real time the hull monitoring information during operations in ice, including early warning, alarming, safety reminder and decision support, etc., so as to provide decision support for the Master.

2.1.5 The flowchart of the monitoring and decision system is shown in Figure 2.1.5.

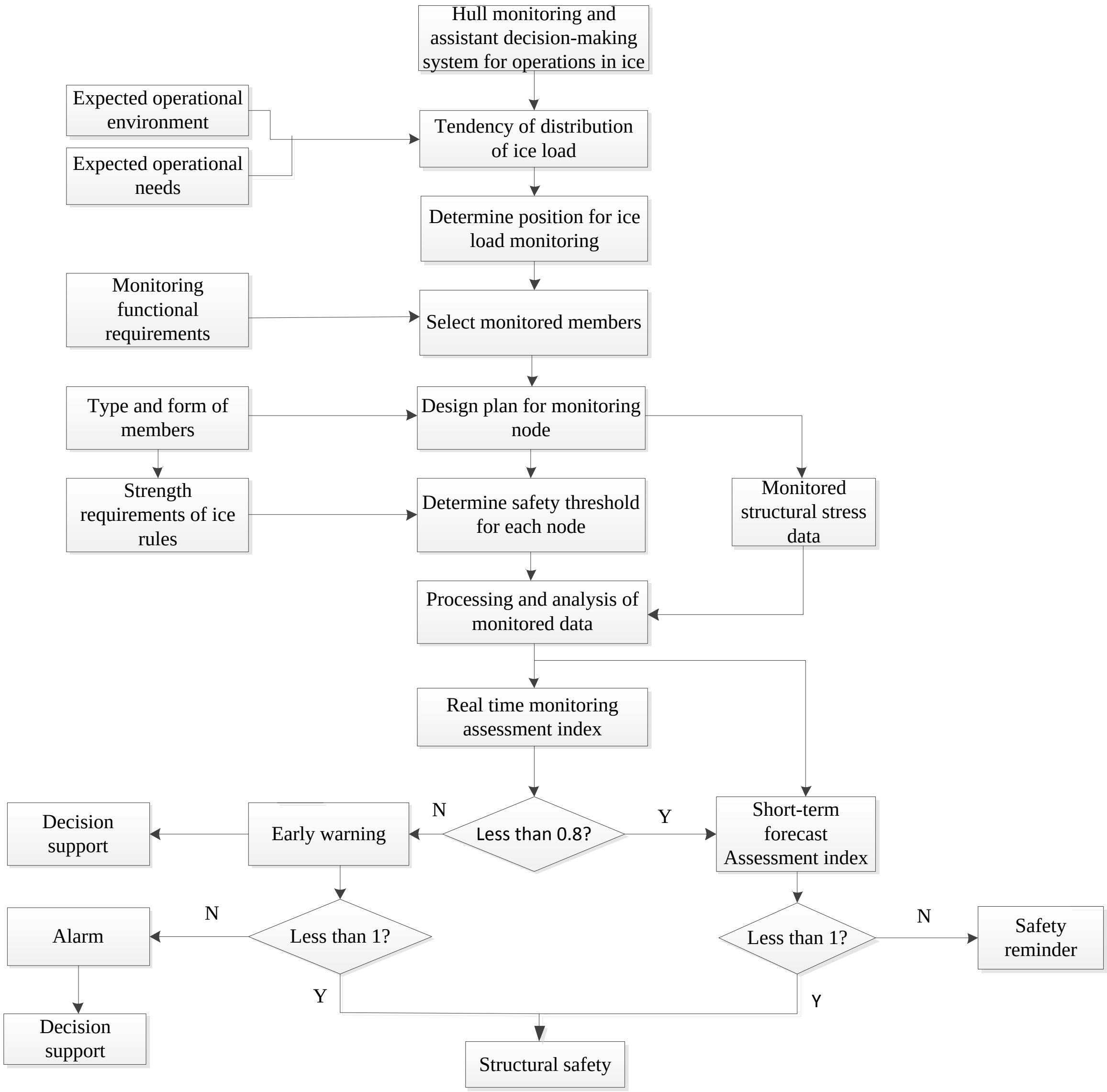



Figure 2.1.5 Flowchart of the monitoring and decision system

## 2.2 Environmental information

2.2.1 The monitoring and decision system is to be able to obtain ice environmental information, .e.g. air temperature, sea water temperature, sea ice type[1] and thickness, intensity, etc., and display relevant information.

2.2.2 The monitoring and decision system is to take measures as necessary to eliminate the effects of ambient temperature on the monitoring data, e.g. by adopting a temperature compensator or using a calculation method taking account of ambient temperature change.

## 2.3 Hull monitoring locations for operations in ice

2.3.1 The monitoring and decision system monitors hull structural responses primarily through strain sensors arranged on hull members near the waterline.

2.3.2 The arrangement locations for sensors of the monitoring and decision system are to be selected based on distribution tendency of ice load. See Figure 2.3.2 and Table 2.3.2.

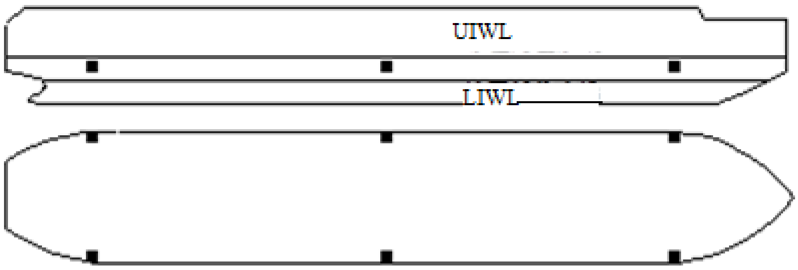



Figure 2.3.2 Arrangement locations for monitoring sensors

Table 2.3.2

| | |
|---|---|
| Arrangement areas | The arrangement areas are to be selected according to the requirements of the Rules for Ice Class between Upper Ice Water Line (UIWL) and Lower Ice Water Line (LIWL). The arrangement locations may be determined according to ice load value forecast, ice load model test, FE analysis of structural stress, etc. |
| Arrangement means | Arrangement means for sensors are to be selected according to different members to be monitored:<br>(1) 45$^o$ bidirectional strain sensors or three-directional strain sensors are arranged on webs;<br>(2) unidirectional strain sensors are arranged on face plates or flanges;<br>(3) three-directional strain sensors are arranged on shell platings. |
| Types of sensors | Fiber grating sensor or resistance strain sensor |

2.3.3 When arranging sensors, short strain sensors are generally used to measure local structural stress caused by ice excitation, and they are to be arranged at the location with the maximum strain.

2.3.4 Proper sensor installation means are to be selected according to different functional requirements for measuring tensile/compressive/bending normal strain or shearing strain, and the influence of temperature change on the measurement is to be taken into account.

## 2.4 Design of typical structural monitoring details

2.4.1 The devices for monitoring strain (stress) of typical structural details of hull for operations in ice are to be designed according to the following principals:

(1) unidirectional strain sensors are provided on face plates or flanges of transverse/longitudinal members to measure tensile/compressive strain (stress) of members during bending;

[1] See sea ice type and thickness as defined by the World Meteorological Organization (WMO).

(2) bidirectional strain sensors are provided on webs of transverse/longitudinal members to measure shearing strain (stress) of webs;

(3) three-directional strain sensors are provided on shell platings to measure maximum main strain (stress) of shell platings;

(4) strain sensors are to be arranged as far away as possible from toe ends of brackets.

2.4.2 Web frames

(1) In general web frames subject to ice impact in the arrangement areas are to be selected. Unidirectional tensile/compressive strain sensors are to be arranged on face plates / flanges at midspan of web frames; bidirectional shearing strain sensors are generally to be arranged at upper and lower ends of span of transverse frames. The design of strain monitoring points is illustrated in Figure 2.4.2.

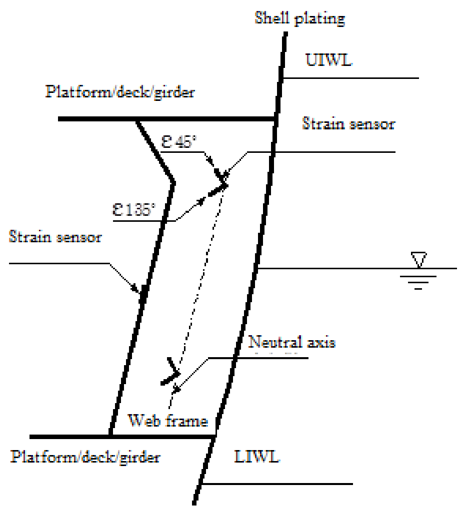



Figure 2.4.2 Monitoring arrangement of web frame strain

(2) For face plates of web frames, tensile/compressive strain sensors may be used to measure tensile/compressive strain and monitor tensile/compressive strain (stress) on face plates of web frames.

(3) For transverse web frames, bidirectional shearing strain sensors may be used to monitor shearing strain (stress) of webs of transverses.

2.4.3 Girders

(1) In general girders subject to ice impact in the arrangement areas are to be selected. Unidirectional tensile/compressive strain sensors are to be arranged on face plates at midspan of girders; bidirectional shearing strain sensors are generally to be arranged at longitudinal members near the transverse ring. The design of strain monitoring points is illustrated in Figure 2.4.3.

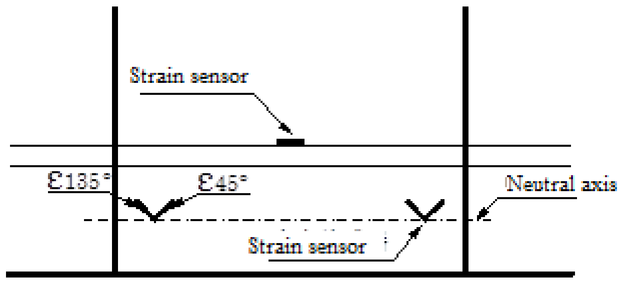



Figure 2.4.3 Monitoring arrangement of girder strain

(2) For face plates of girders, tensile/compressive strain sensors may be used to measure

tensile/compressive strain and monitor tensile/compressive strain (stress) on face plates of girders.

(3) For webs of girders, bidirectional shearing strain sensors may be used to monitor shearing strain (stress) of girders.

2.4.4 Longitudinals

(1) In general longitudinals subject to ice impact in the arrangement areas are to be selected. Unidirectional tensile/compressive strain sensors are to be arranged on face plates at midspan of longitudinals. The design of strain monitoring points is illustrated in Figure 2.4.4.

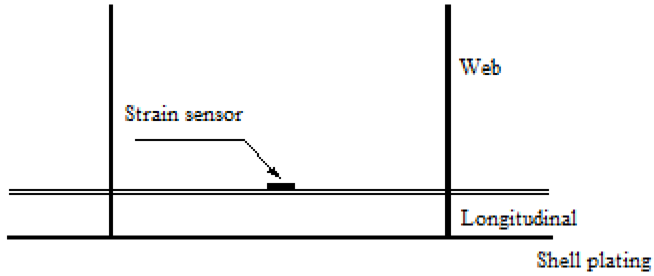



Figure 2.4.4 Monitoring arrangement of longitudinal strain

(2) For face plates of longitudinals, tensile/compressive strain sensors may be used to measure tensile/compressive strain and monitor tensile/compressive strain (stress) on face plates of longitudinals.

2.4.5 Frames

(1) In general frames subject to ice impact in the arrangement areas are to be selected. Unidirectional tensile/compressive strain sensors are to be arranged on face plates at midspan of frames. The design of strain monitoring points is illustrated in Figure 2.4.5.

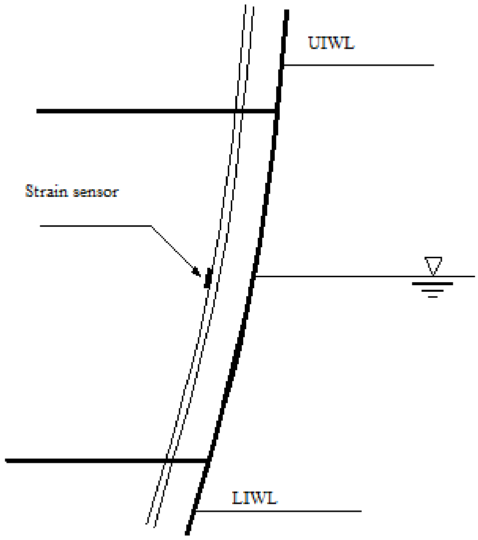
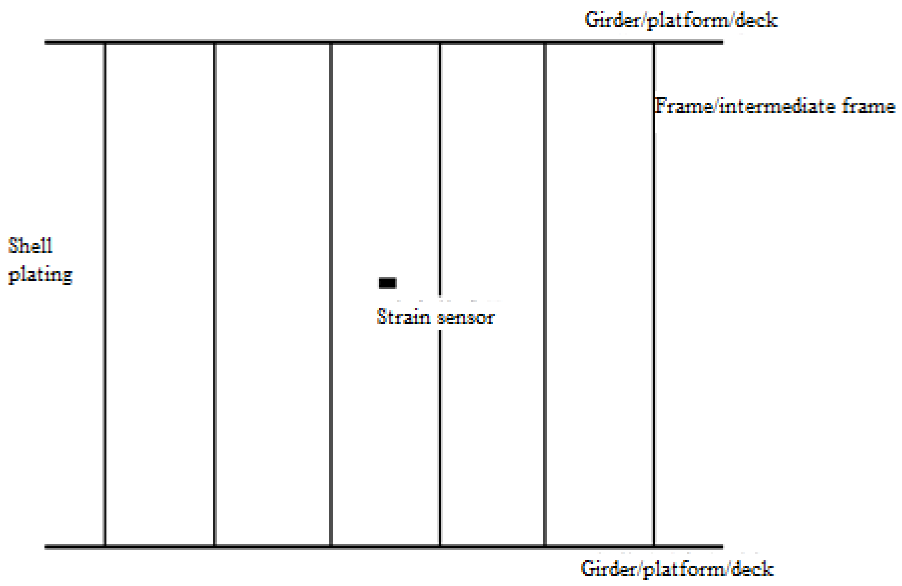



Figure 2.4.5 Monitoring arrangement of frame strain

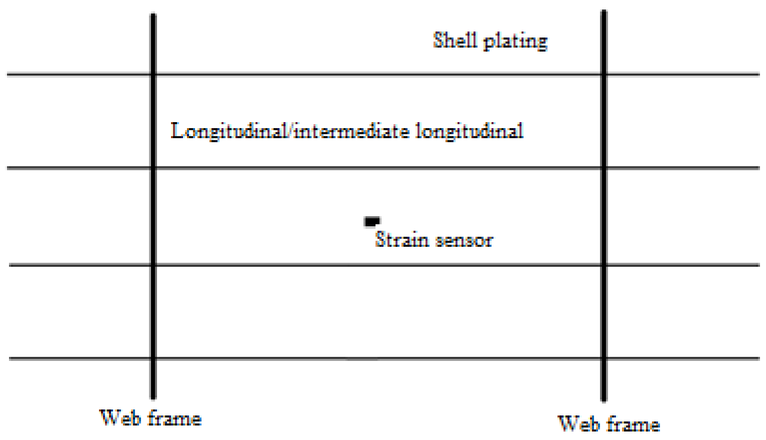
(2) For face plates of frames, tensile/compressive strain sensors may be used to measure tensile/compressive strain and monitor tensile/compressive strain (stress) on face plates of frames.

2.4.6 Shell platings

(1) In general side shell platings subject to ice impact in the arrangement areas are to be selected. Three-directional strain sensors are to be arranged at the center of shell plating panel. The design of strain monitoring points is illustrated in Figure 2.4.6.




(Transversely framed)




(Longitudinally framed)

Figure 2.4.6 Monitoring arrangement of shell plating strain

(2) For shell platings, three-directional strain sensors may be used to measure panel strain and monitor maximum main strain (stress) of shell platings.

**2.5 Processing method for hull monitoring data of operations in ice**

2.5.1 The data collected are to be processed by low-pass filter to filter measurement errors introduced by high frequency noise.

2.5.2 Due to the randomness of ice load distribution and the harsh ice area environment, the probability of abnormal values in the collected data is increased, and the abnormal values which are far from the values of other data samples are to be eliminated during data processing.

2.5.3 Collected hull monitoring data for a ship operating in ice can be used as input for assessment index after being processed such as low-pass filtering and removing abnormal values.

**2.6 Determination of safety threshold**

2.6.1 The monitoring and decision system is specifically used to monitor the response of hull structure under ice load. When the system is started, the initial value for a hull monitoring location is automatically set to zero.

2.6.2 In the monitoring and decision system, the safety threshold is determined by factors such as the location of measurement points, attributes of structural members, and permissible stress. Such threshold is used to evaluate the safety state of members.

2.6.3 For permissible stress of a monitored member under ice load impact deduced according to the requirements of the Rules for Ice Class, see relevant provisions of Chapter 4, PART TWO, or Section 2, Chapter 13, PART EIGHT of CCS Rules for Classification of Sea-going Steel Ships or other equivalent methods.

2.6.4 For ships with PC notations, see Table 2.6.4 for permissible stress of the monitored member under ice load impact.

Table 2.6.4

| Member | | | Permissible stress |
|---|---|---|---|
| Shell plating | Transversely framed $\Omega \geq 70°$ | | $\frac{1}{2(1+\frac{s}{2b})^2} R_{eH}$ |
| Shell plating | Longitudinally framed $\Omega \geq 20°$ | | $\frac{1}{2(1+\frac{s}{2l})^2} R_{eH}$ |
| Shell plating | Longitudinally framed $\Omega < 20°$ | | $\frac{2\frac{b}{s}-(\frac{b}{s})^2}{2(1+\frac{s}{2l})^2} R_{eH}$ |
| Framing | Longitudinal | Bending stress | $A_4 R_{eH}$ |
| Framing | Longitudinal | Shear stress | $\frac{R_{eH}}{2\sqrt{3}}$ |
| Framing | Frame | Bending stress | $Y A_1 R_{eH}$ |
| Framing | Frame | Shear stress | $\frac{R_{eH}}{2\sqrt{3}}$ |
| Bay | Web frames | | Determined by direct analysis |
| Bay | Girder | | Determined by direct analysis |
| Longitudinal strength | Yield/bending | | $\sigma_a - \frac{\bar{M}_s}{W_c} \times 10^3$ |
| Longitudinal strength | shearing | | $\tau_a$ |

Note: For definitions of $\Omega$, $PPF_p$, $s$, $b$, $Y$, $A_1$, $A_4$, $R_{eH}$, $\sigma_a$, $\tau_a$ in the table, see Section 2, Chapter 13, PART EIGHT of CCS Rules for Classification of Sea-going Steel Ships; for definitions of $\bar{M}_s$ and $W_c$, see Section 2, Chapter 2, PART TWO of CCS Rules for Classification of Sea-going Steel Ships.

2.6.5 For ships with B3~B1* notations, see Table 2.6.5 for permissible stress of the monitored member under ice load impact.

Table 2.6.5

| Member | | Permissible stress |
|---|---|---|
| Shell plating | Longitudinally framed | $\frac{0.889}{f_2} R_{eH}$ |
| Shell plating | Transversely framed | $0.667 f_1 R_{eH}$ |

| | | | |
|---|---|---|---|
| Longitudinals & framing | Longitudinal | bending stress | $\frac{8f_4}{m}R_{eH}$ |
| | | Shear stress | $\frac{f_4 f_5}{2\sqrt{3}}R_{eH}$ |
| | Frame | bending stress | $\frac{4}{m_t}R_{eH}$ |
| | | Shear stress | $\frac{f_3}{2\sqrt{3}}R_{eH}$ |
| Strong member | Web frame | | Determined by direct calculation |
| | Girder | | Determined by direct calculation |

Note: For definitions of $f_2$, $f_1$, $f_3$, $f_4$, $f_5$, $R_{eH}$, $m_t$, $m$, see Section 2, Chapter 4, PART TWO of CCS Rules for Classification of Sea-going Steel Ships.

2.6.6 The ratio of maximum measured stress of members to the safety threshold is taken as the assessment index. When the assessment index is greater than or equal to 1, alarm is to be set; when it is greater than or equal to 0.8, early warning is to be set.

### 2.7 Short-term monitoring forecast

2.7.1 The monitoring and decision system is to have the function of short-term monitoring forecast. Based on the existing monitoring data, it can reflect the variation trend of the monitoring data within next 1-2 hours (such as extreme value forecast, trend curve, etc.). When the forecasted assessment index reaches 1, a safety reminder is to be set.

### 2.8 Decision support

2.8.1 Assisted decisions are to be made to support the Master to select appropriate operation measures according to the ice area environment, ship state and early warning/alarm information.

2.8.2 When a ship operates in ice, appropriate operational measures corresponding to early warning/alarm from different locations are to be implemented. A general description is given in Table 2.8.2.

Table 2.8.2

| Early warning/alarm location | Possible danger | Operational measure |
|---|---|---|
| Bow | Damage of bow structure;<br>structural failure of girders and frames at bow | Reducing speed, changing course or stopping operation is recommended |
| Midship | Damage of side shell plating; failure of side girders and frames | Reducing speed or increasing turning radius is recommended |
| Stern | Damage of stern frames;<br>structural failure of girders and floors at stern | Reducing speed is recommended |

## Section 3 Supplementary Requirements for Non-standard Ice Operation Mode

### 3.1 General requirements

3.1.1 When operating in ice, ship structural strength is affected. If there are functional requirements for non-standard ice operation mode, it is recommended to consider relevant requirements of this Section according to the characteristics of ice operation, based on Section 2.

3.1.2 According to selected non-standard ice operation mode, sensors are distributed on corresponding local hull structures and real-time monitoring and forecast are carried out on ice-induced hull structure response, so as to analyze the safety status of relevant structures.

3.1.3 Hull ice load distribution trend during non-standard ice operation and distribution position of sensors can be determined by means of test, numerical analysis method or structure stress finite element analysis.

3.1.4 For the design of structure monitoring nodes, see relevant requirements of 2.4, Section 2 of the Guidelines.

**3.2 Turning operation in ice**

3.2.1 For ships with higher ice operation performance (e.g. with high lifting rudder, with podded propulsion system), in order to meet the need of hull monitoring during turning operation in ice, it is recommended to set additional hull monitoring devices according to the requirements of 3.2.2.

3.2.2 During turning operation, the ice pressure was maximum at two positions: in front of the ship proceeding direction in adjacent to internal side of the shipping lane; and at rear of the ship proceeding direction in adjacent to the external side of the shipping lane. At the same time, ice pressure amidships is higher due to compression of large amount of sea ice. Therefore, based on monitoring positions in Section 2 of the Guidelines, at least one hull monitoring position is to be additionally set in way of critical positions of shoulder and tail structures near molded line contraction respectively, on each side of the vessel.

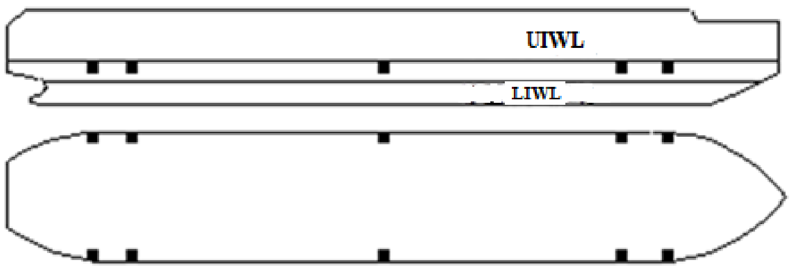



**Figure 3.2.2 Schematic diagram of distribution positions of monitoring sensors**

3.2.3 When there is early warning or alarm, suggestions on correcting ship operation are to be given:

(1) When the ship is subject to turning operation, attention is to be paid to hull monitoring conditions at hull shoulder and stern positions. If early warning/alarm occurs, measures such as slowing down or increasing turning radius may be taken.

(2) For high ice class ships using azimuth thruster, in severe ice conditions, in order to avoid heavy ice load on hull, it is recommended to turn astern at low speed, so as to blow ice away from hull through azimuth thruster and widen the lane, thus facilitating turning. If selecting turning ahead at high speed, it is recommended to control the angle of azimuth thruster within $30^{o}$.

**3.3 Glancing operation in ice**

3.3.1 Ships may adopt ice glancing operation mode (e.g. ice ridge glancing). In order to meet the need of hull monitoring during glancing operation, it is recommended to set additional hull monitoring devices according to the requirements of 3.3.2.

3.3.2 During glancing operation, there is heavy ice impact load in way of the position where the molded line contracts from bow to shoulder, and the bow may be subject to additional impact bending moment and shear force caused by heavy ice load, therefore, hull monitoring positions are to meet following requirements:

(1) At least one hull monitoring position is to be set on each side of the vessel at critical position between the bow and the position where the moulded line contracts. And at least one hull

monitoring position is to be set on each side of the vessel at the position where the molded line contracts.

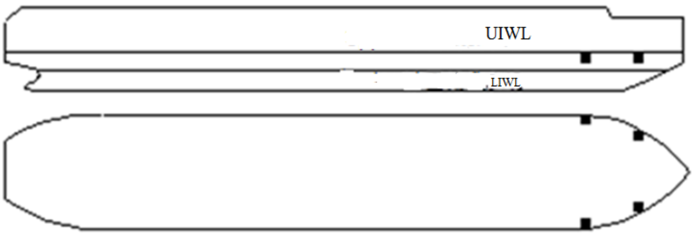



**Figure 3.3.2(1)    Schematic diagram of distribution positions of monitoring sensors**

(2)    At least one hull girder shear strain (stress) monitoring position is to be set at critical position of bow shell plating, as shown in Figure 3.3.2(2), to obtain hull girder shear strain (stress) by installing bidirectional 45$^o$ strain sensor.

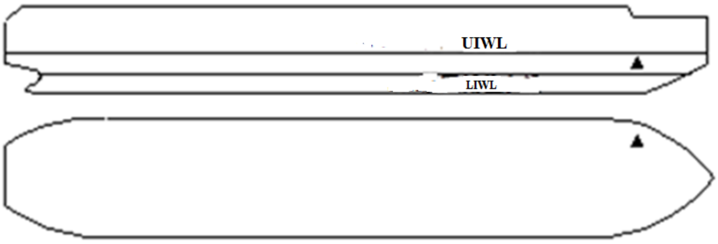



**Figure 3.3.2(2)    Schematic diagram of distribution positions of monitoring sensors**

(3)    At least one hull girder bending moment monitoring position is to be set at critical position of typical transverse section 0.5L~0.7L away from the stern. In order to reduce measurement error and as far as practicable, several strain (stress) monitoring positions may be arranged at equal spacing along ship breadth and an average value is to be taken.

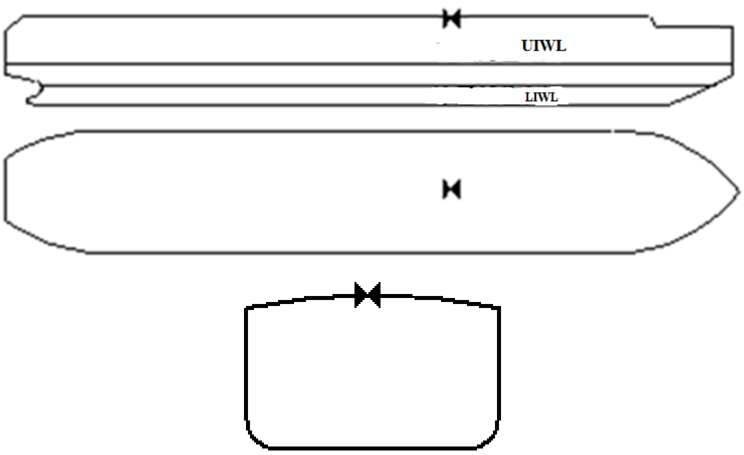



**Figure 3.3.2(3) Schematic diagram of distribution positions of monitoring sensors**

(4)    One three-directional strain (stress) monitoring position is to be set on bow hull plating to measure maximum strain (stress) of hull shell plating.

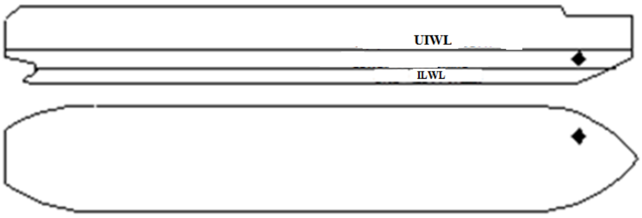



**Figure 3.3.2(4) Schematic diagram of distribution positions of monitoring sensors**

3.3.3 When an early warning or alarm is released, suggestions on correcting ship operation are to be given:

(1) During first year ice glancing operation, if thickness of glancing ice is greater than that of design ice, speed of continuous glancing is to be lower than speed in design ice, and the maximum speed of single glancing is to be the speed in design ice.

(2) During multi-year ice glancing operation, bow glancing is to be used with low glancing speed.

(3) During ice ridge glancing, only bow glancing is allowed and glancing speed is not to be higher than design ice speed.

(4) There is risk of be trapped in ice when colliding with extreme ice barrier, so caution is to be taken when performing colliding operation.

(5) When hull monitoring data approaches or reaches safety threshold, glancing speed is to be reduced or glancing is to be stopped.

**3.4 Stern-ahead operation in ice**

3.4.1 Ships may adopt stern-ahead operation mode in ice region (e.g. ferryboats in ice region, bidirectional operational ships in ice region). In order to meet the need of hull monitoring during stern-ahead operation, it is recommended to set additional hull monitoring devices according to the requirements of 3.4.2.

3.4.2 During stern-ahead operation, there is heavy ice load on ship structure near stern waterline, and especially the positions where the molded line changes greatly withstand the greatest ice pressure, therefore, hull monitoring positions are to comply with following requirements:

(1) At least one hull monitoring position is to be set at critical positions of stern and stern transition zone respectively, on each side of the vessel.

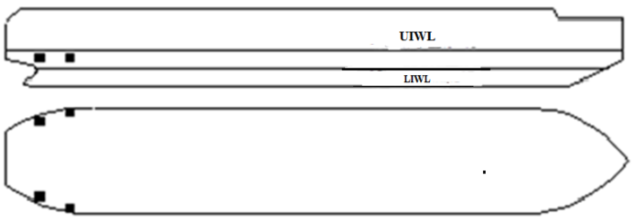



**Figure 3.4.2(1) Schematic diagram of distribution positions of monitoring sensors**

(2) At least one three-directional strain (stress) monitoring position is to be set on stern shell plating to measure the maximum main strain (stress) of hull shell plating.

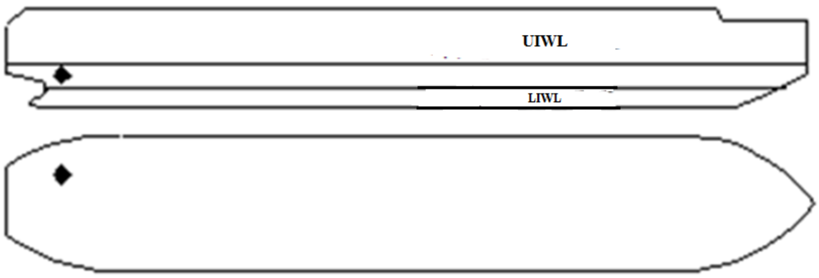



**Figure 3.4.2(2) Schematic diagram of distribution positions of monitoring sensors**

3.4.3 When an early warning or alarm is released, suggestions on correcting ship operation are to be given:

(1) Appropriate propeller immersion at stern is to be maintained as far as possible to prevent damage due to direct ice collision by propeller blade.

(2) During stern-ahead operation in thicker ice region (ice ridge, thick brash ice), low speed and continuous rotation of pod may be adopted to increase efficiency of ice washing.

**3.5 Shallow water operation in ice**

3.5.1 Ships may carry out shallow water operation in ice (e.g. shallow water lane, port operation, etc.). In order to meet the need of hull monitoring during shallow water operation in ice, it is recommended to set additional hull monitoring devices according to the requirements of 3.5.2.

3.5.2 During shallow water operation in ice, bottom area is easy to subject to ice impact, therefore, sufficient numbers of hull monitoring positions are to be set at critical positions of hull bottom area.

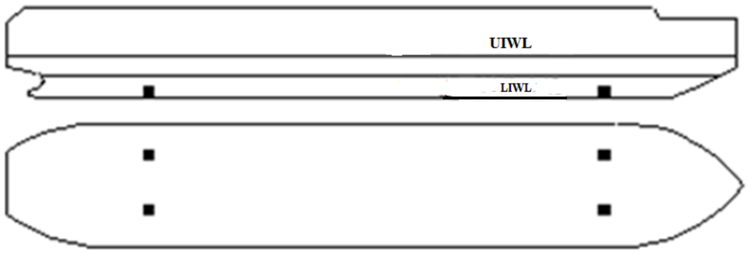



**Figure 3.5.2 Schematic diagram of distribution positions of monitoring sensors**

3.5.3 When an early warning or alarm is released, suggestions on correcting ship operation are to be given:

(1) Attention is to be paid to ship bottom monitoring state. If an early warning/alarm is released according to hull monitoring data, measures such as reducing speed and adjusting course are to be taken and proceeding is to be halted when necessary.

(2) When the ship is subject to severe ice condition, watch out is to be strengthened. Bypassing or slowly accessing from downwind edge of loose ice may be performed when necessary.

**3.6 Oblique operation in ice**

3.6.1 For dedicated icebreakers performing oblique operation in ice, in order to meet the need of hull monitoring during oblique operation in ice, it is recommended to set additional hull monitoring devices according to the requirements of 3.6.2.

3.6.2 During oblique operation in ice, there is large difference between ship-ice interaction and routine ice operation, and hull girder bending moment and shear force at ship side increase significantly, therefore, hull monitoring positions are to meet following requirements:

(1) At least one three-directional strain (stress) monitoring position is to be set on hull shell plating at hull oblique icebreaking position to measure maximum main strain (stress) of hull shell plating.

(2) Hull ice load distribution trend during oblique operation is to be analyzed by means of test or numerical analysis method, and sufficient quantity of hull monitoring positions are to be set in critical positions of hull structure in areas with heavy ice load.

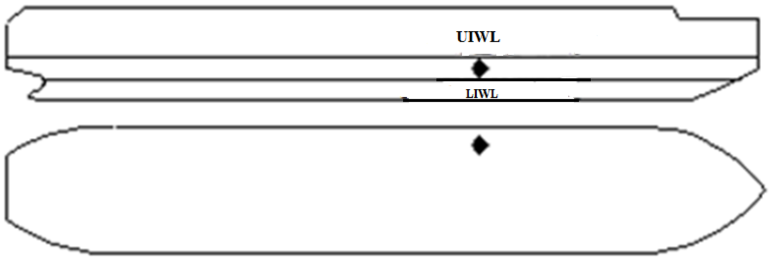



**Figure 3.6.2 Schematic diagram of distribution positions of monitoring sensors**

3.6.3 When an early warning or alarm is released, suggestions on correcting ship operation are to be given:

(1) Oblique operation can increase icebreaking breadth and improve icebreaking efficiency, but it can only be used in area with thinner ice layer. For thick ice layer or ice ridge, oblique operation is to be stopped immediately.

(2) During oblique operation, draught is to be adjusted to near design waterline to advance at speed as low as possible.