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GUIDELINES FOR DEVELOPING CRITERIA FOR SURFACE EFFECT SHIPS SEAKEEPING PERFORMANCE ASSESSMENT

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1. ANEP 47 (Edition 1) on Guidelines for Developing Criteria for Surface Effect Ships Seakeeping Performance Assessment is a NATO UNCLASSIFIED publication.

2. ANEP 47 (Edition 1) is effective NATO-wide upon receipt.

3. ANEP 47 (Edition 1) contains only factual information. Changes to this publication are not subject to ratification prodedures and will be promulgated as necessary by AC/141(IEG/6).

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RECORD OF CHANGES

CHANGE DATE	DATE ENTERED	EFFECTIVE DATE	BY WHOM ENTERED

PREFACE

1. A Surface Effect Ship (SES) is sea-going hovercraft with catamaran type side hulls and flexible seals at the bow and stern, fitted with a lift fan system which creates a continuously pressurised air cushion. The predominant feature of SES which makes this type of vessel attractive is its ability, when cushion borne, to maintain speed higher than those attainable by conventional craft of a similar size. Other advantages include reduced underwater signatures and sensitivity to shock. This document provides designers with guidelines for developing criteria for SES seakeeping performance assessment.

2. This Allied Naval Engineering Publication has been prepared and adopted by IEG/6 Sub Group 5 on Seakeeping.

3. Each Nation is encouraged to use this ANEP in their own design processes in order to provide a basis for standard evaluation of different designs.

4. It is intended that this should be just one of a series of ANEPs to be used in conjunction with STANAG 4154.

GUIDELINES FOR DEVELOPING CRITERIA FOR SURFACE EFFECT SHIPS SEAKEEPING PERFORMANCE ASSESSMENT

Annex

A. General Considerations for SES operations.
B. Ad hoc criteria for SES seakeeping.
C. Recommended computational and experimental procedures for seakeeping predictions.
D. Framework for developing examples of procedures for SES seakeeping assessment.
E. Definitions.
F. References.

Related documents

STANAG 4154: General Criteria and Common Procedures For Seakeeping Performance Assessment.

STANAG 4194: Standardised Wave and Wind Environments and Shipboard Reporting of Sea Conditions.

Aim

1. The aim of ANEP is to establish guidelines for developing criteria for the operability and habitability aspects of SES to be used in the assessment and evaluation of seakeeping qualities in the design phase in order to ensure satisfactory seakeeping qualities.

General

2. The general problems of SES operations affecting seakeeping are described in Annex A. Guidelines for developing criteria for SES seakeeping which must allow satisfactory decisions to be taken during design, based on the current state of the art, are contained in Annex B. The recommended computational and experimental methods for the evaluation of ship seakeeping characteristics at the design stage are outlined in Annex C. A framework for developing examples of procedures for seakeeping assessment illustrating the application of these principles of Annex A and of the general criteria of Annex B using the methods of Annex C are given in Annex D. The definitions are given in Annex E and the references in Annex F.

ANNEX A

GENERAL CONSIDERATIONS FOR SES OPERATIONS

1. A Surface Effect Ship (SES) is a sea-going hovercraft with catamaran type side hulls and flexible seals (for air retention) at the bow and the stern, fitted with a lift fan system which creates a continuously pressurised air cushion.

2. SES can function in two different operating modes:

- cushion borne: the majority of the ship's weight is balanced by the vertical thrust of the air cushion and the remainder by the buoyancy of the hulls and their planing lift.

- hull borne: where the weight of the ship is balanced by the buoyancy of the hulls. The air cushion seal, when not in use, is either lowered into the water, or raised above the water into a stowed position close to the wet deck;

3. The predominant feature of the SES which makes this type of vessel very attractive is its ability, when cushion borne, to maintain speed higher than those attainable by conventional craft of similar size. Other advantages of the SES include reduced underwater signatures and reduced sensitivity to underwater shock. This is due to the fact that the main part of the hull is supported on the air cushion above the water thereby reducing the drag and minimising the influence of the waves.

4. The lift system must be designed to reduce sea induced changes in cushion pressure, and the resulting vertical motion. Lift control and ride control systems may be of two different types:

- an active system which can be designed in two ways: by venting the cushion air through sets of controlled louvres (ride control system) or by controlling the air intake to the fans;

- a passive system

5. The high speed of the SES allows it to carry out successfully a wide range of missions such as:

Navy missions:
- ASW,
- tracking and shadowing shipping with a high strategic interest; decoy of enemy forces
- rapid response preventing the enemy from deploying his forces
- coverage of wide areas in search or defensive barrier operations,
- rapid and unexpected projection of offensive capabilities.
- MCMV

Coast guard missions:
- search and rescue
- enforcement of laws and treaties
- protection of the marine environment
- fisheries support
- EEZ protection.

6. The seakeeping phenomena to be analysed are: air cushion dynamics, motions, accelerations, deck wetness, wet deck slamming, added resistance and loss of propulsive efficiency, wave impact and slamming on the hull structural members (such as plating or primary girder), either hull borne or cushion borne and dynamic stability.

The seakeeping phenomena adversely influences the crew and the ship's various systems as well as the ship's performance. These detrimental effects may be grouped under three main headings:

a. crew: performance degradation, fatigue, motion sickness, work restrictions, injury, loss overboard;

b. systems: damage from crash landing, damage from inertial loads, damage from wave impact, damage from fatigue.

c. payload: performance degradation of weapons and sensors, strain and damage on equipment, increased corrosion.

7. These effects might, individually or collectively, bring about a decision to modify or cancel operations. The aim of giving due consideration to seakeeping in the design process is to reduce the severity of these effects to an acceptable level so that the ship can carry out her mission in the designated sea state.

8. Under the present state of the art, it is impossible to evaluate rigorously performance degradation of the crew and ship's systems, and hence formulate an overall performance index as a function of the ship's motions. However, present knowledge does allow the formulation of ad hoc criteria for the seakeeping phenomena. In addition, these criteria are comparable with existing procedures for predicting seakeeping behaviour and are suitable as a result for use in the SES design process.

9. In the design process, seakeeping qualities are established by attention to:

a. overall and local structural strength

b. geometry, L/B ratio, underwater hull shape, weight distribution, trim and radii of gyration

c. lift fan system, ride control system and configuration of the seals, cushion design pressure and lift factors.

d. arrangements (ie layout of crew accommodation and work spaces)

e. the clearance of the wet deck in relation to the sea (both hull borne and cushion borne).

10. Under the current state of the art of technology, the effects of seakeeping phenomena on the crew, structure and equipment are dealt with in the course of the design process by specifying acceptable levels of the ship's motion at the designated sea state and for the intended missions. The ship is then designed to fulfil these conditions. A minimum set of specifications, is defined in the following table:

Design Detail	Seakeeping Quality
overall and local structural strength	- frequency and severity of: bow structure on impact bottom slamming wet deck slamming seal impact on waves
geometry, L/B, underwater, shape, trim, weight, distribution	- roll - lateral accelerations at a certain number of locations - a measure of ride quality which takes into account the effect of vertical motions on crew performance. - lateral motions - pitch - surge - vertical accelerations at a number of locations - propulsive plant performance degradation - added resistance
air cushion dynamics, lift fan system, ride control system, configuration of the seals, cushion design pressure and lift factors	- lift system power - lift and ride control performance - seal system performance
arrangements (ie layout of crew accommodation and work spaces)	- weapon performance - crew performance
the clearance of the wet deck in relation to the sea (both hull borne and cushion borne)	- wet deck slamming - heave response characteristics

11. For SES, the evaluation of seakeeping performance must be considered not only as a design tool, but also as a means of providing detailed information to the commanding officer to allow him to exploit fully the capacities of the ship without undue risk for crew, equipment and structure.

12. The formulation of ad hoc criteria and guidelines for each of the above aspects of seakeeping is examined in Annex B.

ANNEX B

AD HOC CRITERIA FOR SES SEAKEEPING

1. The effects of sea state on crew, structures and equipment are addressed in the design process by specifying on the one hand acceptable levels of ship motions in one environment and in given operational conditions and, on the other, by designing a ship to meet these limits. Criteria and limits depend on the intended missions/tasks and equipment sensitivity. Design criteria must also take into account the possible future requirements of interoperability of ships which are expected to participate in joint NATO operations.

2. A minimum set of seakeeping phenomena which must be considered in an SES design, and which concerns the use of the SES, in conjunction with the factors which govern the definition of criteria for each of these aspects of seakeeping are given below:

Phenomenon	Factor governing criteria
impact of slamming , impact of bow seal	- Primary and local structure strength - material fatigue - crew tolerance to impact
pitch, surge, roll, vertical and lateral motions and accelerations, motion coupling	- ride quality - crew performance degradation - motion-induced interruptions - fatigue and motion sickness - whole-body vibrationproblems - work restrictions - equipment specifications - dynamic load factors
involuntary speed loss	- increased resistance - propulsive efficiency - air ingestion effects on propulsor cooling and propulsor performance
deck wetness	- requirements for crew to work on weather deck - equipment specifications
static, dynamic, intact and damaged stability	- safety - KG height - roll radius of gyration - side hull geometry (ie outer dead-rise angle) slenderness - arrangements
directional stability	- yaw control and safety - LCG - fixed or mobile appendages

3. It has to be emphasised that the seakeeping criteria must be given in a form which takes into account the stochastic nature of the environment (waves). For example, a roll limit may be expressed as the maximum allowable standard deviation (rms) of roll angle.

4. In the seakeeping evaluation process a range of operational conditions must be considered. These are defined by:

ship condition:	displacement,metacentric height, radius of gyration, trim;
environment:	wave and wind conditions, short or long crested sea;
mission objective:	task, speed, mode of operation, heading in relation to wind and wave.

5. General criteria for each of the seakeeping phenomena listed under § 2 are described below, with the two types of operation - hull-borne or cushion borne - being dealt with separately as required.

6. Bow impact, slamming and bow seal impact. The criteria applicable to these phenomena are derived from an examination of hull and/or seal system damage risk and operability. Structural design criteria for the hull structure and seal system (skirts, fingers, etc), have to be set for the intended mission profile, the designated sea state and the operational area. These criteria must take account of both local and overall maximum loads. The limit criteria also depend on various factors listed below, with reference to the two modes of operation.

a. cushion borne operation

- local loads on forward hulls
- inertial loads on the equipment and the hulls due to bow impact
- local loads on the bow seal
- crew tolerance to bow impact which may be established by comparing the characteristics of the new model with those of another SES known for its good behaviour

b. hull borne operation

- local loads on the forward hulls and inertial loads on equipment due to slamming
- local loads on the wet deck
- loads on the hull girders
- local loads on bow seals

7. The criteria applied to good seakeeping behaviour are derived from operability considerations in the case of cushion borne condition and habitability considerations in both hull borne and cushion borne conditions, taking into account the human body behaviour in the presence of movements of the ship. These criteria must take into account the fact that SES has relatively high speed missions, resulting in movements at higher frequencies than conventional vessels. The high frequencies imposed on personnel by the SES can create biodynamic problems such as loss of fine motor skills which are not normally experienced on naval ships. The least complex criterion would take the form of limits on vertical/lateral accelerations at specified locations on the ship.

8. The criteria applicable to pitch, surge, roll, vertical and lateral movements are derived from operability considerations in both the hull borne and cushion borne conditions. The limits are set as standard deviations of the various motions. These limits are derived from equipment specifications.

9. The criteria applicable to the lift system are derived from operability conditions in the case of cushion borne navigation. In rough water the lift system must deliver air in sufficient quantities to the cushion:

- to provide the correct air flow rate to minimise drag while maintaining the volume of the cushion,
- to provide the desired ride quality,
- to replenish quickly the cushion pressure when this is degraded by the waves.

10. The criteria governing reduction in the performance of the propulsive equipment are derived from operability considerations for the propulsive machinery in the cushion borne condition. Two cases are covered:

- propulsion by water jets; cavitation of the pump and air ingestion are to be avoided,
- propulsion by propeller; the emergence of the propeller is to be avoided.

If these conditions are encountered propulsive system problems may occur leading to engine failure.

11. The criteria governing deck wetness are to be expressed on the basis of formulae on deck wetness probability at a sufficient number of stations to be used along the longitudinal axis of the ship. These effects of shipping water on equipment, personnel and visibility should be considered. The effects of spray must also be considered.

12. The criteria for stability are formulated to avoid the risk of dangerous behaviour. Capsize, broaching and nose diving, high speed turning or when reacting to a system malfunction are important considerations. Static stability depends on the metacentric height and hull shape (flare angle, dead-rise angle, etc). Dynamic stability depends on the deadrise angle and slenderness. In fact this value determines the orientation of the forces on the sidewalls and their relative position with respect to the vertical centre of gravity.

13. The criteria for directional stability are formulated on the basis of acceptable handling qualities which enable the ship to operate in full scale operations. Adequate directional stability is usually obtained during design by analysing the behaviour of the ship in calm sea. This analysis takes into account the reactions of the ship to malfunctions of the controls.

ANNEX C

RECOMMENDED COMPUTATIONAL AND EXPERIMENTAL PROCEDURES FOR SES SEAKEEPING EVALUATION

1. This Annex identifies the recommended computational and experimental procedures for forecasting, from the design stage, the nautical qualities and the SES seakeeping qualities. These methods can also be used to evaluate the quality of existing SES. We emphasise that these methods are only suggested procedures and that the adoption of other methods with a comparable or higher accuracy is not precluded. This is an area of intensive research where improvements in the near future can be expected.

2. The methods are grouped into twelve categories which will each be examined for the two types of operation: hull borne or cushion borne.

a. specification of sea spectra
b. SES motion response
c. bow impact
d. slamming
e. deck wetness and spray
f. ride quality
g. propulsive performance degradation
h. lift system models
i. stability
j. mission profile
k. limiting criteria
l. operability evaluation (or operational suitability)

3. Specification of sea spectra. The definition of the seaway, wind force and areas of operation are of prime importance. For each area of operation a range of wave spectra must be identified by using related document No 2 on this subject and its associated reference documents; References 6, 8 and 17 contain further information. It is stressed that a minimum of two parameters (significant wave height and wave modal period) must be used to specify seaway spectra. In addition, for a given wave height, it is important to cover a realistic range of characteristic wave periods as some aspects of seakeeping are very sensitive to wave period. Documents should be consulted to obtain the proper statistical distribution of the wave period for a given wave height for the areas of operational interest. Account should also be taken of the fact that the seas are usually short crested to some degree and therefore a spreading function should be selected for this purpose.

4. Motions of the SES. In hull borne condition an SES is a catamaran and a linear strip theory based programme can be used. The linear character of the theory allows us to apply the principle of superposition provided that the incident seaway can be considered as the sum of regular waves, ie harmonics.

For cushion borne operations motion computations, in the frequency domain (linearised approach) and in the time domain (with inclusion of certain non-linearities), can be used to evaluate the SES motions. The mathematical model must be adjusted to reflect the configuration of the seal system, the trim control system and the directional control system of the model.

Model tests in regular and irregular waves can be used for examining cushion borne performance. It must be noted that the models can become too large or too fast for the test facilities, with the result that an experimental manned craft is required. It is also noted that the cushion pressure does not follow Froude scaling. Useful data and general ideas on this subject, including discussion of the problems linked with the scaling of the cushion pressure, are given in the references. The following method is recommended for motion predictions at the design stage:

a. Strip theory based numeric codes for hull borne navigation.

b. Numerical codes for dealing with cushion borne navigation.

c. Model tests for both hull borne and cushion borne conditions.

5. Bow impact. A method which recognises the probabilistic character of this phenomenon must be used. It will have to include the following elements: type of navigation of the SES (hull borne or cushion borne), hull clearance, wave steepness, characteristics of the lift control system. The determination of the hull-girder loads resulting from hydrodynamic impacts will be carried out with the help of a method such as the one indicated in reference 18; a further study of the slamming pressures can be done using references 11 and 12. In order to have an estimate of this phenomenon occurrence probability, model tests in regular and irregular waves are currently the only reliable source of data. In conclusion, the following methods are recommended.

a. model tests in regular and irregular waves

b. analytical methods for primary and local loads.

6. Slamming. Few validated computational methods can be recommended for SES slamming prediction. Useful computations can be done for hull borne navigation, while taking into account the low operational speed of the ship in this condition (see references: 2, 9, 19 and 20). The following procedures can provide information:

a. strip theory based calculation codes (reference 17) for hull borne condition.

b. model tests in regular and irregular waves in both hull borne/cushion borne conditions.

7. Deck wetness and Spray. The probability of deck wetness can be predicted by standard methods described in the seakeeping literature. Methods of estimating the

severity of deck wetness are given in reference 9. The model and full-scale tests are the only reliable source of information on the dynamic pressure generated by green water crashing onto the deck. Even more important are the effects of heavy spray, CFD methods can be used to examine air flow around the bow to minimise upwards flow of spray.

8. Ride quality. Methods for quantitative assessment of the ride quality of naval vehicles are still in the development stage. The methods which can be used are neither very accurate nor very reliable. They should take into account motion sickness, motion-induced interruptions, motion-induced fatigue and whole-body vibrations. They should also take into account the duration of exposure and the frequency of movements and accelerations. References 4, 5,10, 25 and 26 provide guidance on this topic.

9. Propulsive performance degradation. Depending on the type of propulsion used - screw propeller or water jet - a method for computing the decrease in the propulsive coefficients,and the associated loss of speed caused by the sea state must be used in both navigation conditions (hull borne and cushion borne). For screw propellers it must take account of the increased resistance and of the efficiency decrease caused by the disturbance of the flow which feeds the screw in a disturbed sea. For the water jet, it must take account of the increased resistance and of the efficiency decrease caused by the disturbance of the flow which feeds the intake ducts; pump cavitation phenomena can have a considerable effect in this case. No reliable computational methods have been developed so far and it is recommended that model tests in regular and irregular waves are undertaken.

10. Lift system models. The study of the static operation of the lift system can be done with the help of relatively simple numeric models. More sophisticated models may allow us to deal with dynamic cases. A more complete study of dynamic phenomena requires the creation of models fitted with instruments. While taking into account the scaling effect on aerodynamic phenomena of the air cushion, the use of SES models intended for the tank tests may turn out to be inadequate. It is possible to create special models of only the air cushion (air supply system, loss of pressure, volumes) and, where the dynamic excitation caused by the sea is controlled by leak flows which vary in intensity and frequency (controlled valves). The degree of reliability of these methods is still not accurately known.

11. Stability. In the hull borne condition, the study of stability can be best dealt with by conventional methods. The study of cushion borne condition (references 23 and 24) shows that the usual stability criteria are not suited to the SES. The complete numerical modelling of an SES inserting cushion borne condition, hydrodynamic effects and the actions of the appendages can provide information on stability. However, allowing for the unstationary nature of the phenomena involved and the coupling effects between the various motions, only a complete series of experiments with models can guarantee reliably the roll stability of SES type ships.

12. **Mission profile.** The wide range of missions likely to be performed by SES type ships, as stated in Annex A, demands a clear definition of mission profile before beginning with the evaluation of the seakeeping of an SES type ship. The setting of an operational mission scenario must make it possible to define the operational areas and the conditions in which the ship will have to cross certain areas. In particular, a mission may require an SES to use its two modes of navigation (hull borne or cushion borne) in different sea conditions.

13. **Limiting criteria.** The limiting criteria are associated with both the ship and the mission. The criteria generally applied to conventional ships can be adopted in part of the SES. However, for the SES makes this process inadequate, especially the high frequency of encountering waves at high speed may lead to considerations not just of the amplitude of certain movements but also the period as a criterion for the accomplishment of certain tasks. The definition of precise criteria adapted to the for the SES will only be obtained by having available the results of the operational performance of the existing craft of this type.

14. **Operability assessment (operability suitability).** The assessment of the operational suitability of an SES is obtained by comparing the results of the SES seakeeping assessment with the limiting criteria. This comparison makes it possible to define the envelope of conditions in which the ship is capable of guaranteeing a set of criteria, and thus, statistically, of fulfilling its mission. This envelope will include sea states and headings in relation to the waves.

15. A framework for developing examples is given in Annex D.

ANNEX D

FRAMEWORK FOR DEVELOPING EXAMPLES OF PROCEDURES FOR SES SEAKEEPING ASSESSMENT

1. This Annex provides a framework for developing examples of the procedures described in Annex C.

2. Ship comparison. The compatibility of NATO ships for joint operations can be assessed by the following procedure:

a. specify the operational scenario including the mission to be performed and the range of conditions (sea state and other relevant environmental factors, ship speed and heading in relation to the waves);

b. specify the ships which are to accomplish the mission and, while referring to Annex B, state the seakeeping criteria applicable to these ships for the mission. (Ships and criteria must be specified jointly because criteria can be ship dependent);

c. determine the seakeeping characteristics of each ship used on the basis of the procedures described in Annex C. These characteristics should be determined for the range of conditions specified in a. and expressed in terms of the criteria of b.;

d. for each ship, compare the results of c. with the criteria specified in b. Define the subset of the conditions specified in a. in which each ship can perform the mission concerned;

e. compare the results of d. for the ships evaluated. This comparison assesses the suitability of each of the ships to perform successfully the operational scenario specified in a.

ANNEX E

DEFINITIONS

ACC	Air cushion catamaran
ACV	Air cushion vehicle
Added resistance	In calm seas at a given speed, the ship experiences a certain resistance to forward movement. This resistance increases by a quantity called "added resistance" in rough seas
Amplitude	Difference between the mean value and the peak (or trough) value of an oscillatory movement
ANV	Advanced Naval Vehicle
Broaching	Phenomenon which causes a ship to veer and present side to wind and waves as a result of the strong link which exists, in a following sea, between yaw and roll.
Cushion borne	When the ship is partly lifted by the lift system (its draught is reduced).
Deck Wetness	Deck wetness is usually considered when a relative displacement at the FP is equal to the freeboard at the FP. This ignores the effects of bow flare or swell up which affect the onset of deck wetness and spray
Directional Stability	The directional stability of the ship is the ability or otherwise to return to a straight path when momentarily deflected by an external disturbance from an initial straight path, the rudder remaining amidships.
EEZ	Exclusive Economic Zone. Maritime areas over which a given country has exclusive exploitation rights on surface and deep sea areas.
Green water	Water shipped on the deck of a ship in heavy seas, as distinct from spray.

Heading	Relative course of the ship in relation to the predominant direction of the waves or wind 0 degrees = following 45 degrees = quartering 90 degrees = beam 135 degrees = bow 180 degrees = head.
Heave	Oscillatory vertical motion of ship's centre of gravity
Hull borne	Mode of navigation where the weight of the ship is completely balanced by the buoyancy on two lateral keels
Involuntary loss of speed	For a given output of engine power, the speed of a ship islower in a seaway than in calm seas. This reduction in speed is called "involuntary loss of speed"
Irregular waves	System of waves in which the heights and periods are not constant. It is "long crested" when the direction of the waves is unique (unidirectional) and "short crested" when the direction of the waves is not unique (multidirectional)
Lift control system	All the electronic, electric, hydraulic and mechanical components which are required to control the air pressure in the cushion
Local structure	The hull structure close to the part where the concentrated loads appear
Metacentric height	The vertical distance separating the centre of gravity fromthe metacentre. This parameter governs in particular the "stiffness" during roll (period of the movement)
Pitch	Oscillatory angular motion about a lateral horizontal axis
Primary or principal structure	Main structure of the hull
Propeller emergence	Emergence of part or of the whole propeller from the water

Regular waves	Waves whose height and period are constant. Such waves are not representative of reality, but are currently used for theoretical studies or in test tanks
Retrieving system	All the electric, hydraulic and mechanical components required to lift the seal (skirt, finger, etc) and thus facilitate hull borne navigation
Ride control system	RCS; the variations in the level of the system intended to control the pressure in the cushion in such a way as to limit high frequency vertical movements which may reduce comfort
Ride quality	Measurement of the movement of the ship in terms of the comfort of the crew and their capability to keep the same performance as on calm seas. Also known as the human factor
RMS	RMS (root mean square) indicates the standard deviation of a given statistical dimension
Roll	Oscillatory angular motion about a horizontal longitudinal axis
Sea state	Generic term describing the state of roughness of the sea. There is no precise definition, but numeric scales of the sea state (force) which take into account the significant height of the waves have been proposed
Seal	More or less flexible system, closing the cubic contents contained between the two lateral keels, making the bow and stern of the SES more or less watertight
SES	Surface Effect Ship
Significant wave height	If all wave heights (peak to trough) of a wave record are measured, the significant height is the mean value of the upper third of all the wave heights. It is approximately equal to the height estimated visually by an observer.
Slamming	When, in a seaway, the ship's bottom, after re-emerging, re-enters the sea, an impact can occur and high pressures may be produced on a reduced sea. The resulting impulse is called "bottom shock" or "slamming". Similar effects can occur in the case of ships presenting highly flared parts or on the transverse structure of two hull ships (SES - SWATH).

Spectrum	Law giving the amplitude or energy of the different frequent components of a given time signal
Superstructure	The part of the ship above the main hull
Surge	Oscillatory horizontal longitudinal motion of the ship's centre of gravity
Sway	Oscillatory horizontal lateral movement of the ship's centre of gravity
Worst heading	The course evaluated in relation to the average direction of the waves which will produce the severest movement. This heading will depend on the movement involved.
Yaw	Oscillatory angular motion about a vertical axis

ANNEX F

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