（別紙2）

国 海 環 第 1 号
国 海 運 第 2 号
平成 22 年 4 月 6 日

（社）日本旅客船協会会長
日本内航海運組合総連合会会長
（社）日本船主協会会長
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国土交通省海事局
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フェリー、RORO 船の操船について
（注意喚起）

昨年 11 月、熊野灘を航行中の大型フェリー（全長：167m、総トン数：7,910 トン）が、航行中に大傾斜し、その後、三重県御浜町沖に座礁する事故が発生しました。

この事故の調査を実施している運輸安全委員会から本年 3 月 24 日に進捗状況報告（参考資料参照）が公表されました。同報告では、復原性の低下する追い波中の航行により傾斜が発生し、この傾斜で生じた荷崩れにより 40 度程度の大傾斜となった可能性があるとの推定がなされています。

追い波中での復原性の低下はよく知られた現象で、国際海事機関（IMO）から出されている「荒天中の操船ガイドライン」（以下、「IMOガイドライン」という。）にもその危険性と操船上の注意事項が示されています。今般、同種の事故の再発防止の観点から、IMOガイドラインに示されている追い波中での危険性と操船上の注意事項の要点を別添のとおり取りまとめましたので、傘下のフェリー事業者及びフェリーと同様の運航形態にある RORO 船の事業者に対し、注意喚起を実施していただきますようお願いします。

なお、運輸安全委員会の進捗状況報告により事故原因に関する一定の情報が明らかとなってきていることから、海事局では有識者による委員会を設置して事故再発防止対策の検討を行う予定としておりますので、念のため申し添えます。

平成 22 年４月
国土交通省海事局

追い波中での操船について　（注意喚起）

平成 21 年 11 月、三重県熊野灘沖を航行中の大型フェリー（全長：１６7m、総トン数：7,910 トン）が航行中に大傾斜し、その後海岸に座礁する事故が発生しました。この事故の調査を実施している運輸安全委員会から本年３月 24 日に進捗状況報告が公表されました。同報告では、復原性の低下する追い波中の航行で傾斜が発生し、この傾斜で生じた荷崩れにより 40 度程度の大傾斜となった可能性があるとの推定がなされています。

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追い波航行中の危険性

船体が波頂に乗った状態では、水中にある船体形状の変化によって復原性が低下します。追い波状態では、船体が波頂に乗る時間が長くなるので危険性が大きくなります。波長が船の長さの 0.6 倍から 2.3 倍の状態では特に注意が必要で、波高が高くなるほど復原性の低下が著しくな

ります。

　また、追い波中の航行では、復原性の低下により横揺周期が長くなり、波周期と横揺れ周期が一致した場合には横揺れが増幅される同調横揺れが発生する危険性があります。また、波周期と復原性の変化によって大きな横揺れが生じるパラメトリック横揺れの危険性もあります。

追い波中の危険性を回避するための操船上の注意事項

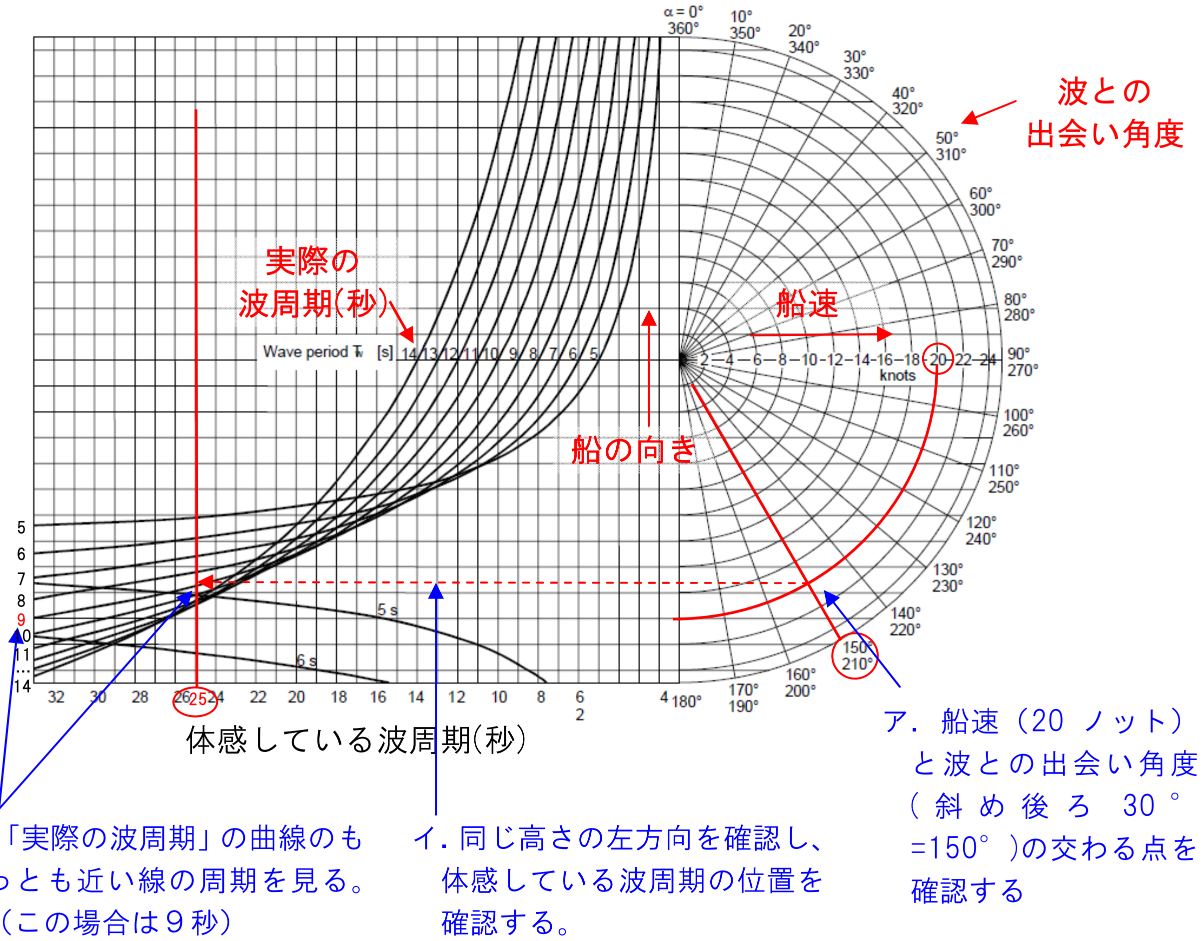
　波長の長い大きな波を後ろから受ける状況下で、波周期と船速がある一定の関係になると、船が波の影響を非常に強く受け、「危険な状態」になることがあります。特に、比較的船速が大きいフェリーやRORO船では、周期の長い追い波の影響を強く受けることがあります。

　このため、特に体感周期の長い追い波中を航行しているときは、以下の①、②、③の方法で、自船の状態が「危険な状態」に入っていないか確認し、「危険な状態」となっている場合は**減速するなどの方法**で「危険な状態」を回避することが重要です。

① *船上で体感している波周期から実際の波周期、波長を求める。*

　船が自ら移動している影響で、船上で体感している波周期と、海面での実際の波周期は異なってきます。以下のグラフを用いれば、体感している波周期と波との出会い角度、船速から、海面での実際の波周期と波長を求めることができます。

例：船速 20 ノット、体感周期 25 秒で、波を斜め後ろ 30°方向から受けている場合
⇒　以下のア～ウの手順で、実際の波周期は約９秒とわかる。



実際の波周期がわかったら、以下の式を用いて、波長を求めます。

波長（m）＝1.56×波周期の二乗

上記の例の場合、波長は 1.56×81＝126mとなります。

② 波長と波高から*「波長の長い大きな波」を受けている状態かを確認する。*

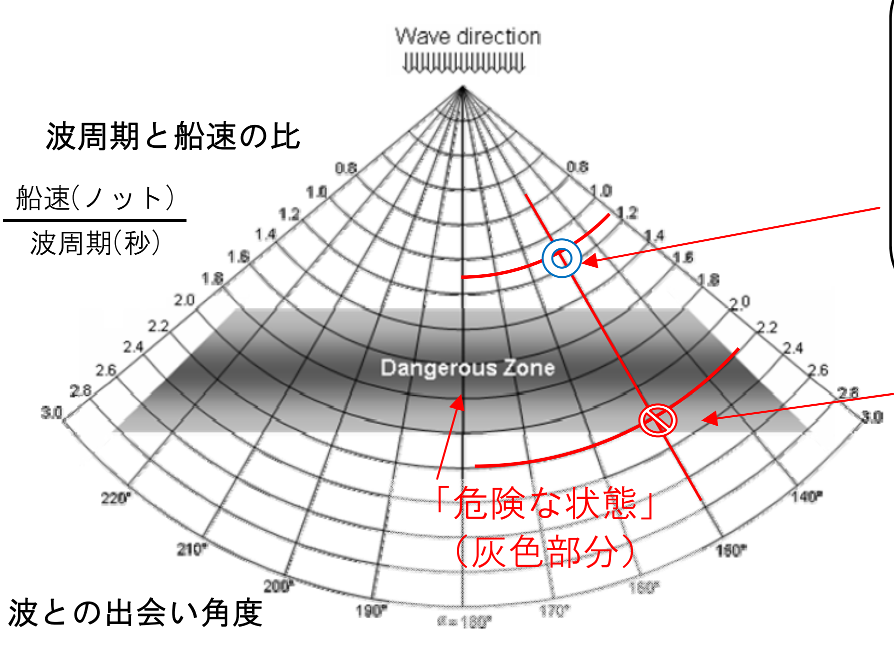
「波長が船の長さ（Lpp：垂線間長）の 0.6 倍以上」で「波高（有義波高）が船の長さ（Lpp：垂線間長）の 0.04 倍以上」となっている場

合には、「波長の長い大きな波」を受けている状態となっていますので、③に進みます。

> 例：Lpp120m、観測される有義波高５ｍ
> ⇒　0.6×120＝72m≦126m、0.04×120＝4.8m≦５ｍで「波長の長い大きな波」を受けている状態となっています。

③　*波周期と船速、波との出会い角度から「危険な状態」に入っていないか確認する。*

体感している波周期から実際の波周期がわかったら、実際の波周期と船速から、自船が「危険な状態」に入っていないか確認することができます。



> 例１：船速 10 ノット、左斜め後ろ 30 度から周期 9 秒の追い波を受けている場合
> ⇒ 波周期と船速の比が 1.11 となり、危険領域を回避している

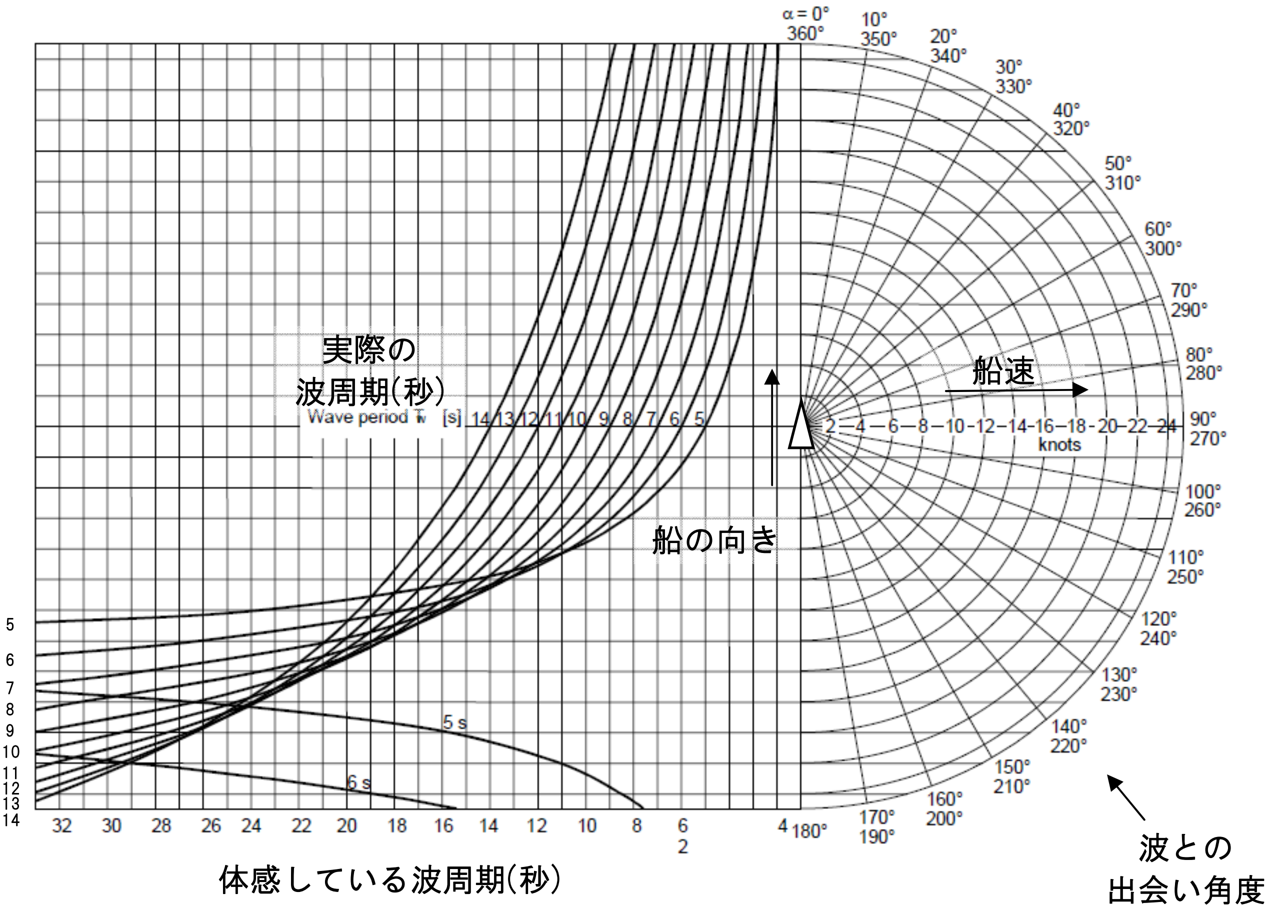
> 例２：船速 20 ノット、左斜め後ろ 30 度から周期 9 秒の追い波を受けている場合
> ⇒波周期と船速の比が 2.22 となり、危険領域に入っている

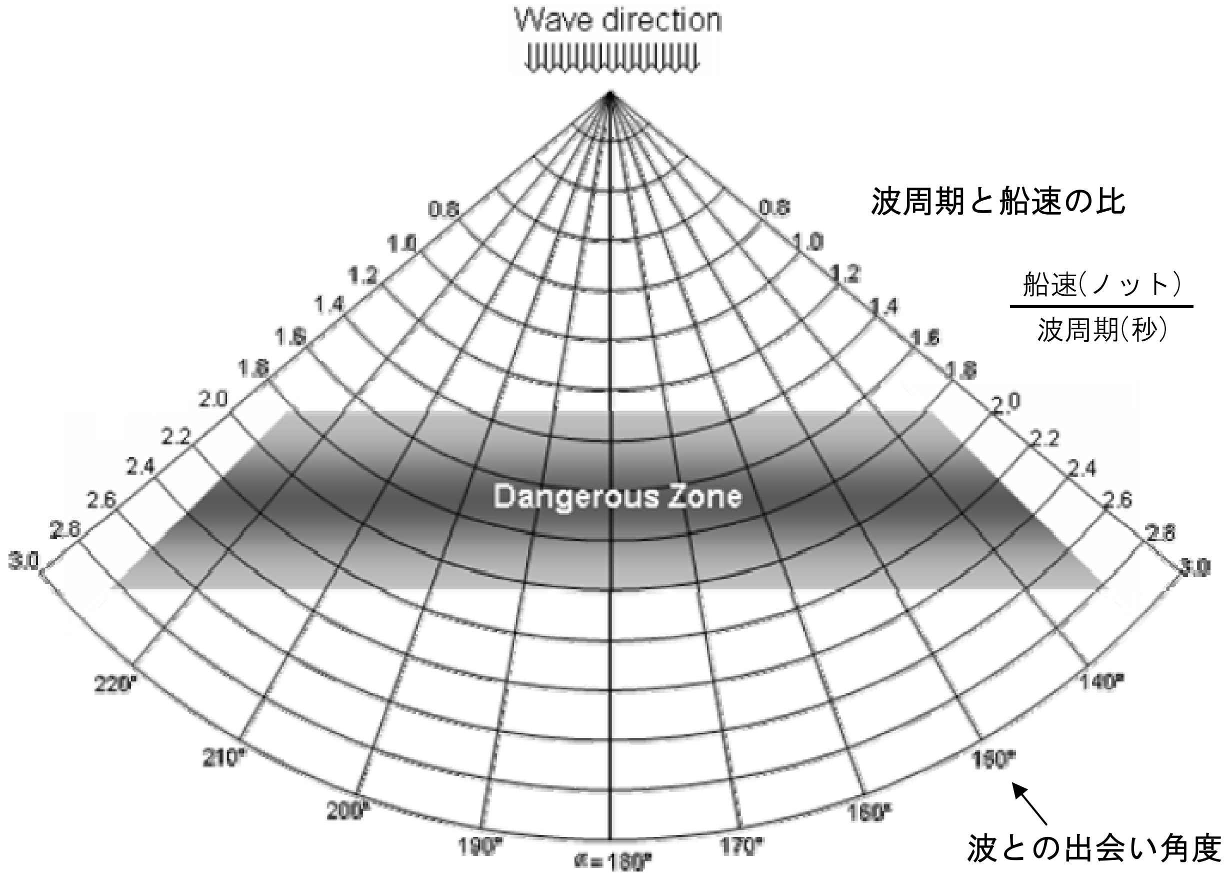
回避の方法

航行中に、上の「危険な状態」に該当するような波周期・波との出会い角度の波を受けている場合は、**減速する・針路を変えるなどの方法**で、「危険な状態」を回避することが重要です。

また、自動操舵（オートパイロット）で航行している場合は、手動操舵に切り替えて、船首揺れ（ヨーイング）に注意して船体が波間に入らないように船首を立てて操舵することも有効です。

追い波航行中の「危険な状態」を確認するためのグラフ





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MSC.1/Circ.1228
11 January 2007

REVISED GUIDANCE TO THE MASTER FOR AVOIDING DANGEROUS SITUATIONS IN ADVERSE WEATHER AND SEA CONDITIONS

1 The Maritime Safety Committee, at its eighty-second session (29 November to 8 December 2006), approved the Revised Guidance to the master for avoiding dangerous situations in adverse weather and sea conditions, set out in the annex, with a view to providing masters with a basis for decision making on ship handling in adverse weather and sea conditions, thus assisting them to avoid dangerous phenomena that they may encounter in such circumstances.

2 Member Governments are invited to bring the annexed Revised Guidance to the attention of interested parties as they deem appropriate.

3 This Revised Guidance supersedes the Guidance to the master for avoiding dangerous situations in following and quartering seas (MSC/Circ.707).

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ANNEX

REVISED GUIDANCE TO THE MASTER FOR AVOIDING DANGEROUS SITUATIONS IN ADVERSE WEATHER AND SEA CONDITIONS

1 GENERAL

1.1 Adverse weather conditions, for the purpose of the following guidelines, include wind induced waves or heavy swell. Some combinations of wave length and wave height under certain operation conditions may lead to dangerous situations for ships complying with the IS Code. However, description of adverse weather conditions below shall not preclude a ship master from taking reasonable action in less severe conditions if it appears necessary.

1.2 When sailing in adverse weather conditions, a ship is likely to encounter various kinds of dangerous phenomena, which may lead to capsizing or severe roll motions causing damage to cargo, equipment and persons on board. The sensitivity of a ship to dangerous phenomena will depend on the actual stability parameters, hull geometry, ship size and ship speed. This implies that the vulnerability to dangerous responses, including capsizing, and its probability of occurrence in a particular sea state may differ for each ship.

1.3 On ships which are equipped with an on-board computer for stability evaluations, and which use specially developed software which takes into account the main particulars, actual stability and dynamic characteristics of the individual ship in the real voyage conditions, such software should be approved by the Administration. Results derived from such calculations should only be regarded as a supporting tool during the decision making process.

1.4 Waves should be observed regularly. In particular, the wave period T_W should be measured by means of a stop watch as the time span between the generation of a foam patch by a breaking wave and its reappearance after passing the wave trough. The wave length λ is determined either by visual observation in comparison with the ship length or by reading the mean distance between successive wave crests on the radar images of waves.

1.5 The wave period and the wave length λ are related as follows:

$$\lambda = 1.56 \cdot T_W^2 \text{ [m] or } T_W = 0.8\sqrt{\lambda} \text{ [s]}$$

1.6 The period of encounter T_E could be either measured as the period of pitching by using stop watch or calculated by the formula:

$$T_E = \frac{3T_W^2}{3T_W + V\cos(\alpha)} \text{ [s]}$$

where V = ship's speed [knots]; and
α = angle between keel direction and wave direction ($\alpha = 0°$ means head sea)

1.7 The diagram in figure 1 may as well be used for the determination of the period of encounter.

1.8 The height of significant waves should also be estimated.

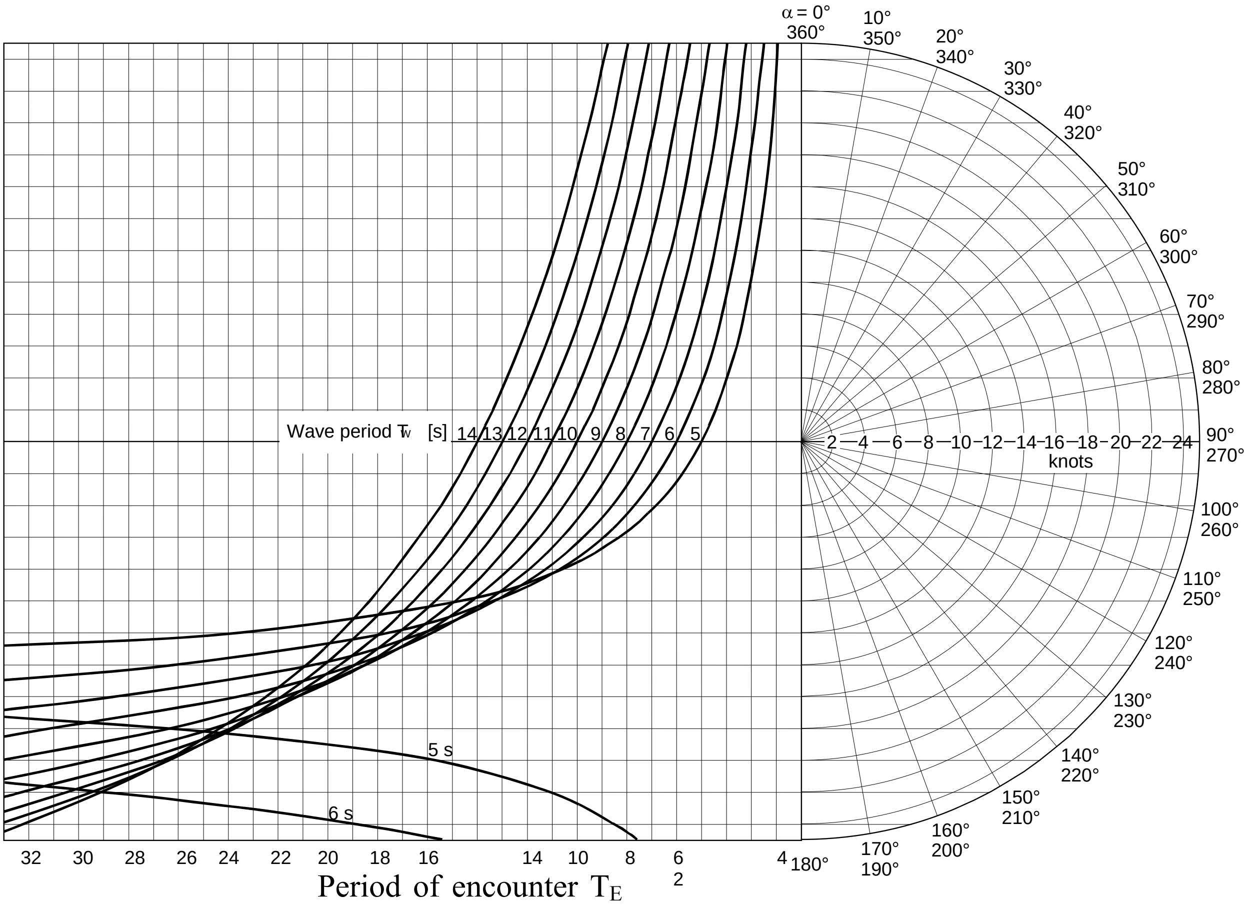

Figure 1: Determination of the period of encounter T_E

2 CAUTIONS

2.1 It should be noted that this guidance to the master has been designed to accommodate for all types of merchant ships. Therefore, being of a general nature, the guidance may be too restrictive for certain ships with more favourable dynamic properties, or too generous for certain other ships. A ship could be unsafe even outside the dangerous zones defined in this guidance if the stability of the ship is insufficient. Masters are requested to use this guidance with fair observation of the particular features of the ship and her behaviour in heavy weather.

2.2 It should further be noted that this guidance is restricted to hazards in adverse weather conditions that may cause capsizing of the vessel or heavy rolling with a risk of damage. Other hazards and risks in adverse weather conditions, like damage through slamming, longitudinal or torsional stresses, special effects of waves in shallow water or current, risk of collision or stranding, are not addressed in this guidance and must be additionally considered when deciding on an appropriate course and speed in adverse weather conditions.

2.3 The master should ascertain that his ship complies with the stability criteria specified in the IS Code or an equivalent thereto. Appropriate measures should be taken to assure the ship's watertight integrity. Securing of cargo and equipment should be re-checked. The ship's natural period of roll T_R should be estimated by observing roll motions in calm sea.

3 DANGEROUS PHENOMENA

3.1 Phenomena occurring in following and quartering seas

A ship sailing in following or stern quartering seas encounters the waves with a longer period than in beam, head or bow waves, and principal dangers caused in such situation are as follows:

3.1.1 Surf-riding and broaching-to

When a ship is situated on the steep forefront of a high wave in following or quartering sea conditions, the ship can be accelerated to ride on the wave. This is known as surf-riding. In this situation the so-called broaching-to phenomenon may occur, which endangers the ship to capsizing as a result of a sudden change of the ship's heading and unexpected large heeling.

3.1.2 Reduction of intact stability when riding a wave crest amidships

When a ship is riding on the wave crest, the intact stability can be decreased substantially according to changes of the submerged hull form. This stability reduction may become critical for wave lengths within the range of 0.6 L up to 2.3 L, where L is the ship's length in metres. Within this range the amount of stability reduction is nearly proportional to the wave height. This situation is particularly dangerous in following and quartering seas, because the duration of riding on the wave crest, which corresponds to the time interval of reduced stability, becomes longer.

3.2 Synchronous rolling motion

Large rolling motions may be excited when the natural rolling period of a ship coincides with the encounter wave period. In case of navigation in following and quartering seas this may happen when the transverse stability of the ship is marginal and therefore the natural roll period becomes longer.

3.3 Parametric roll motions

3.3.1 Parametric roll motions with large and dangerous roll amplitudes in waves are due to the variation of stability between the position on the wave crest and the position in the wave trough. Parametric rolling may occur in two different situations:

.1 The stability varies with an encounter period T_E that is about equal to the roll period T_R of the ship (encounter ratio 1:1). The stability attains a minimum once during each roll period. This situation is characterized by asymmetric rolling, i.e. the amplitude with the wave crest amidships is much greater than the amplitude to the other side. Due to the tendency of retarded up-righting from the large amplitude, the roll period T_R may adapt to the encounter period to a certain extent, so that this kind of parametric rolling may occur with a wide bandwidth of encounter periods. In quartering seas a transition to harmonic resonance may become noticeable.

.2 The stability varies with an encounter period T_E that is approximately equal to half the roll period T_R of the ship (encounter ratio 1:0.5). The stability attains a minimum twice during each roll period. In following or quartering seas, where the encounter period becomes larger than the wave period, this may only occur with very large roll periods T_R, indicating a marginal intact stability. The result is symmetric rolling with large amplitudes, again with the tendency of adapting the ship response to the period of encounter due to reduction of stability on the wave crest. Parametric rolling with encounter ratio 1:0.5 may also occur in head and bow seas.

3.3.2 Other than in following or quartering seas, where the variation of stability is solely effected by the waves passing along the vessel, the frequently heavy heaving and/or pitching in head or bow seas may contribute to the magnitude of the stability variation, in particular due to the periodical immersion and emersion of the flared stern frames and bow flare of modern ships. This may lead to severe parametric roll motions even with small wave induced stability variations.

3.3.3 The ship's pitching and heaving periods usually equals the encounter period with the waves. How much the pitching motion contributes to the parametric roll motion depends on the timing (coupling) between the pitching and rolling motion.

3.4 Combination of various dangerous phenomena

The dynamic behaviour of a ship in following and quartering seas is very complex. Ship motion is three-dimensional and various detrimental factors or dangerous phenomena like additional heeling moments due to deck-edge submerging, water shipping and trapping on deck or cargo shift due to large roll motions may occur in combination with the above mentioned phenomena, simultaneously or consecutively. This may create extremely dangerous combinations, which may cause ship capsize.

4 OPERATIONAL GUIDANCE

The shipmaster is recommended to take the following procedures of ship handling to avoid the dangerous situations when navigating in severe weather conditions.

4.1 Ship condition

This guidance is applicable to all types of conventional ships navigating in rough seas, provided the stability criteria specified in resolution A.749(18), as amended by resolution MSC.75(69), are satisfied.

4.2 How to avoid dangerous conditions

4.2.1 For surf-riding and broaching-to

Surf-riding and broaching-to may occur when the angle of encounter is in the range 135°<α<225° and the ship speed is higher than $\left(1.8\sqrt{L}\right)/\cos\left(180-\alpha\right)$ (knots). To avoid surf riding, and possible broaching the ship speed, the course or both should be taken outside the dangerous region reported in figure 2.

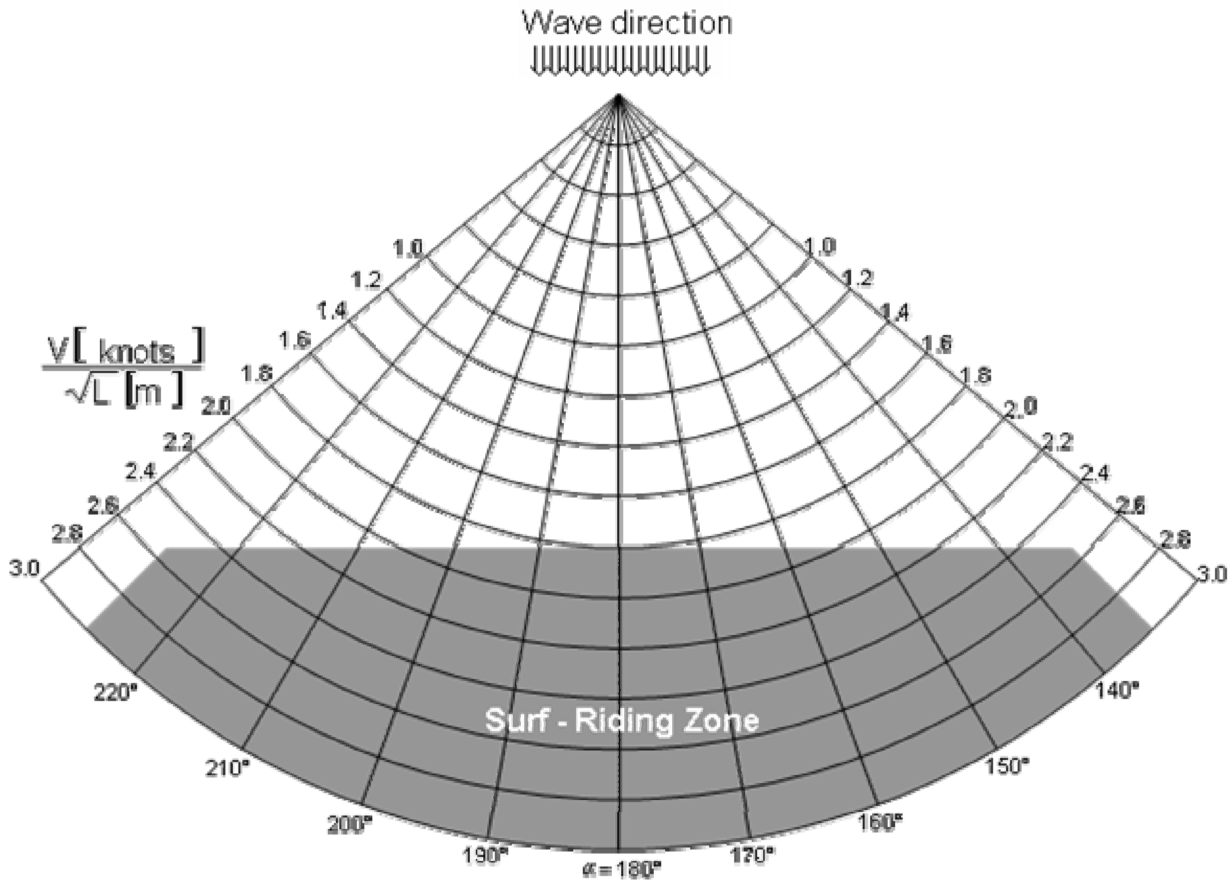

Figure 2: Risk of surf-riding in following or quartering seas

4.2.2 For successive high-wave attack

4.2.2.1 When the average wave length is larger than 0.8 L and the significant wave height is larger than 0.04 L, and at the same time some indices of dangerous behaviour of the ship can be clearly seen, the master should pay attention not to enter in the dangerous zone as indicated in figure 3. When the ship is situated in this dangerous zone, the ship speed should be reduced or the ship course should be changed to prevent successive attack of high waves, which could induce the danger due to the reduction of intact stability, synchronous rolling motions, parametric rolling motions or combination of various phenomena.

4.2.2.2 The dangerous zone indicated in figure 3 corresponds to such conditions for which the encounter wave period (T_E) is nearly equal to double (i.e., about 1.8-3.0 times) of the wave period (T_W) (according to figure 1 or paragraph 1.4).

4.2.3 For synchronous rolling and parametric rolling motions

4.2.3.1 The master should prevent a synchronous rolling motion which will occur when the encounter wave period T_E is nearly equal to the natural rolling period of ship T_R.

4.2.3.2 For avoiding parametric rolling in following, quartering, head, bow or beam seas the course and speed of the ship should be selected in a way to avoid conditions for which the encounter period is close to the ship roll period ($T_E \approx T_R$) or the encounter period is close to one half of the ship roll period ($T_E \approx 0.5 \cdot T_R$).

4.2.3.3 The period of encounter T_E may be determined from figure 1 by entering with the ship's speed in knots, the encounter angle α and the wave period T_W.

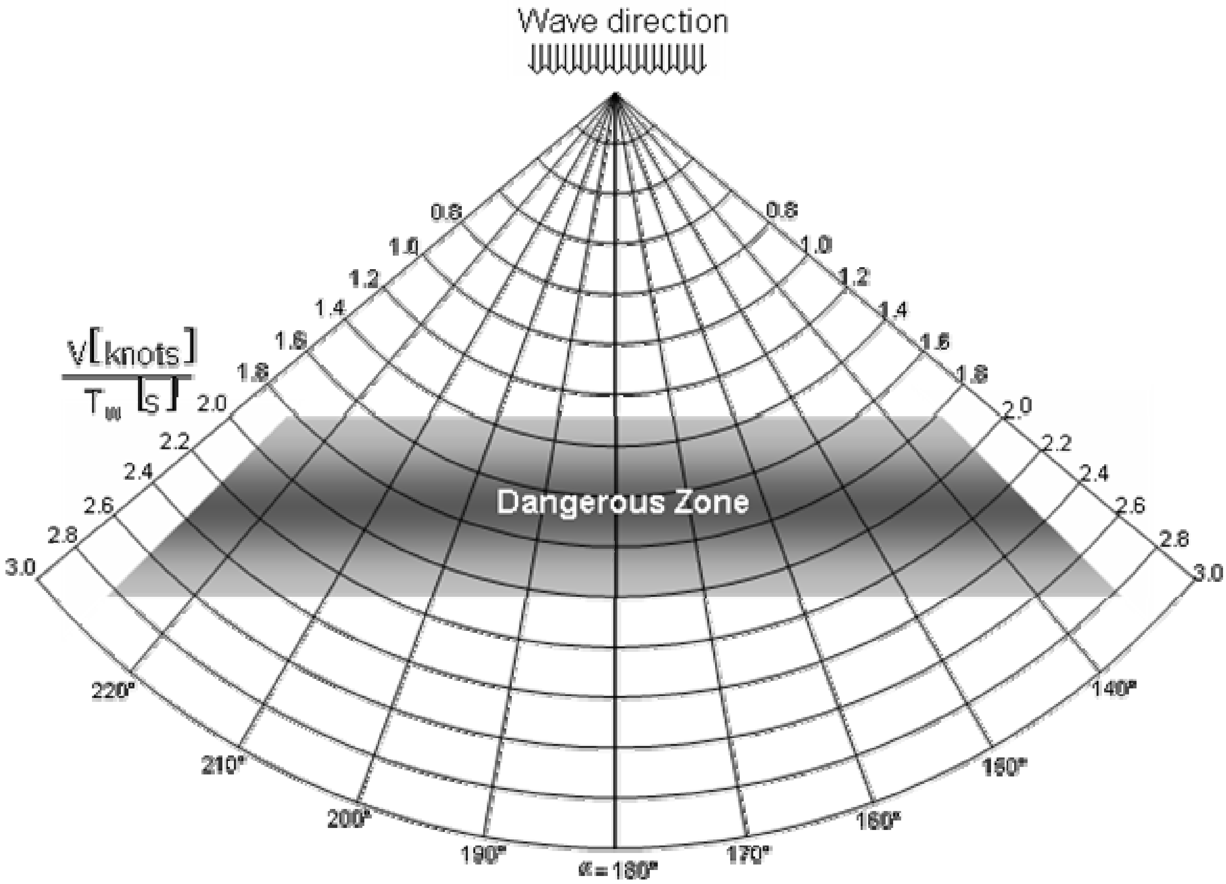

Figure 3: Risk of successive high wave attack in following and quartering seas

Abbreviations and symbols

Symbols	Explanation	Units
T_W	wave period	s
λ	wave length	m
T_E	encounter period with waves	s
α	angle of encounter (α = 0° in head sea, α = 90° for sea from starboard side)	degrees
V	ship's speed	knots
T_R	natural period of roll of ship	s
L	length of ship (between perpendiculars)	m

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