Criteria for Minimum Powering and Maneuverability in Adverse Weather Conditions

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Abstract: The 2012 guidelines on the method of calculation of the attained Energy Efficiency Design Index (EEDI) for new ships, MEPC.212(63), represent a major step forward in implementing energy efficiency regulations for ships, MEPC.203(62), through the introduction of specifications for calculating the EEDI for various types of ships. There are, however, concerns regarding the sufficiency of propulsion power and steering devices to maintain manoeuvrability of ships in adverse conditions, hence safety of ships, if the EEDI requirements are achieved by simply reducing the installed engine power. In the frame of a review of current EEDI provisions, the paper discusses possible criteria required to ensure ship's manoeuvrability and safety under adverse conditions and proposes a way ahead regarding the implementation of these criteria by numerical methods and model tests.

Key words: Manoeuvrability; Minimum Power; Adverse Conditions; EEDI; Ship Safety

1. Introduction

The introduction of EEDI regulations in MARPOL facilitates drastic improvement of energy efficiency of ships and reduction of GHG impact of shipping operations. There are, however, concerns regarding the sufficiency of propulsion power and steering devices to maintain manoeuvrability of ships under adverse conditions, hence the safety of ships, if the EEDI requirements are achieved by simply reducing the installed engine power. Following a proposal from the International Association of Classification Societies (IACS), the following requirement was added to the Reg. 21, Ch. 4 of MARPOL Annex VI: *For each ship to which this regulation applies, the installed propulsion power shall not be less than the propulsion power needed to maintain the manoeuvrability of the ship under adverse conditions as defined in the guidelines to be developed by the Organization*. Work carried out by IACS to develop such guidelines [1-4] served as basis for the Interim Guidelines for Determining Minimum Propulsion Power to Maintain the Manoeuvrability of Ship in Adverse Weather Conditions, MSC-MEPC.2/Circ.1 (2012), updated in Res. MEPC.232 (65) [5].

In relation to this, a new European research project called SHOPERA [6], funded by the European Commission in the frame of FP7, was launched in October 2013, aiming at addressing the challenges of this issue by in-depth research studies and submission of main results for consideration to IMO-MEPC in 2016. A strong European RTD consortium was formed, representing the whole spectrum of the European maritime industry, including classification societies, universities, research organisations and model basins, ship designers, shipyards and ship operators. The project will

- develop and fine-tune hydrodynamic analysis methods for manoeuvring of ships in complex environmental conditions
- perform seakeeping and manoeuvring model tests in seaway to provide basis for the validation of numerical methods
- integrate hydrodynamic analysis tools into a ship design software platform and perform multi-objective holistic optimisation, balancing economy, efficiency and safety
- develop new guidelines for sufficient manoeuvrability in adverse weather conditions

- put together teams of designers, shipyards, owners, classification societies and national administrations to conduct investigations on the impact of the proposed guidelines on design and operation of various ship types

2. Definitions

The following terminology is used herein:

- *functional requirements* (avoiding collision, maintaining and changing speed or course, transit, stopping, rescue etc.) are used to set up the framework of new guidelines;
- *criteria* refer to ship characteristics which are defined in idealized situations (e.g. turning and course-keeping and -changing abilities);
- corresponding *measures* quantify ship's performance in idealized situations (turning diameter, stopping distance, maximum wave height for course-keeping etc.) and
- *standards* (or *norms*) set the limits on these measures for the ship to be considered fulfilling the defined requirements.

3. Existing Regulations

Manoeuvrability in waves is an issue of both ship's powering and manoeuvrability in waves, thus also of seakeeping. Ship's powering and efficiency are regulated by the EEDI provisions; manoeuvrability has been considered in the past more as an issue of operation rather than design; however, once it was realized that some uniform minimum requirements to manoeuvrability are necessary, IMO introduced the Interim Standards for Ship Manoeuvrability, A.751(18), which were revised and finally adopted in 2002 [7]. These standards address turning, initial turning, yaw-checking, course-keeping and emergence stopping abilities by geometrical measures of selected standard manoeuvres in calm water (advance and tactical diameter in turning circle, distance for heading change by 10° due to rudder angle change by 10°, first and second overshoot angles in 10°/10° and the first overshoot angle in the 20°/20° zig-zag manoeuvres and advance until full stop in emergency stopping).

IMO's Manoeuvrability Standards have been criticized by some authors, e.g. [8], for not addressing ship manoeuvrability at low speed, in restricted areas and in wind, waves and currents[8]. Because the task of steering is not only turning, course-keeping and stopping, but also withstanding environmental forces (e.g. to keep or change course and speed), and because different ships react in a different way to environmental forces, norming ship's steering ability in waves seems an *essential* part of *minimum manoeuvrability requirements*.

However, this issue has not been addressed by regulations so far. IACS gathered requirements of classification societies regarding redundancy of the propulsion system [9] as a preparation to the development of performance criteria for safe navigation in adverse conditions. In general, these requirements require the ability to change heading into position of less resistance to the waves and wind and maintain this heading, to keep a prescribed minimum advance speed, or a combination of these two requirements. IACS work towards 2013 Interim Guidelines [5] elaborated on functional requirements to manoeuvrability in adverse conditions [1,2], which led to the following two criteria in [3,4]: the ship must be able to keep a *prescribed course* at *advance speed of at least 4.0 knots* in waves and wind from any direction, which are elaborated in the following.

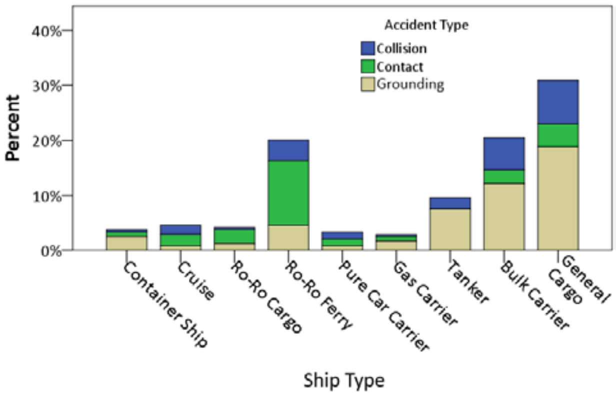
4. Manoeuvrability in Adverse Conditions

Ship's master knows the performance of his ship in adverse conditions; thus, at least in the open sea, he can decide how close the ship can come to a storm, depending on the ship size and type, freeboard, type of cargo, dynamic stability, engine power and steering devices. However, reliable weather forecast and routing are not always possible. In violent weather conditions, no engine power will help as the ship will be mainly driven by the weather; however, turning against the seaway will still be possible, for which a period of less severe seas is selected, and the heading is changed as fast as possible.

Manoeuvring in coastal waters is more demanding and important, than in the open sea. The usual practice in a growing storm in coastal waters is to look for a shelter or, if there is no safe escape, move away from the coast and take a position with enough room for drifting away; grounding, stranding and contact accidents in heavy weather suggest however that there are notable exceptions. The most frequent cause of grounding accidents in a growing storm is waiting at anchor until it starts dragging; after that, engine may be started too late or at too low power. However, in several occasions [10-13] vessels were not able to move away from the coast despite full engine power applied. Although in accident [10] full engine power was not available due to failure of one of the engines, in accident [11] forward speed was reduced in the approach channel to the port to wait for entrance clearance by an outward-bound vessel, and in accidents [12,13] full engine power was available and applied, such accidents suggest that there is a minimum limit for the installed power for a ship to be able to leave a coastal area in a growing storm.

Experience shows that a specific manoeuvring problem of ship types with large windage area is manoeuvring at low speed in restricted areas in strong wind (and usually current) without significant seaway.

An indicative sample of results of a comprehensive statistical analysis [14] of ship accidents[1] in adverse sea conditions is given in Figures 1 to 4.



[1] Accident period 1980-2013; ships over 400GT built after 1980; accidents related to adverse/heavy weather conditions, excluding poor visibility (e.g. fog)

Figure 1. Percentage of ship types by accident types

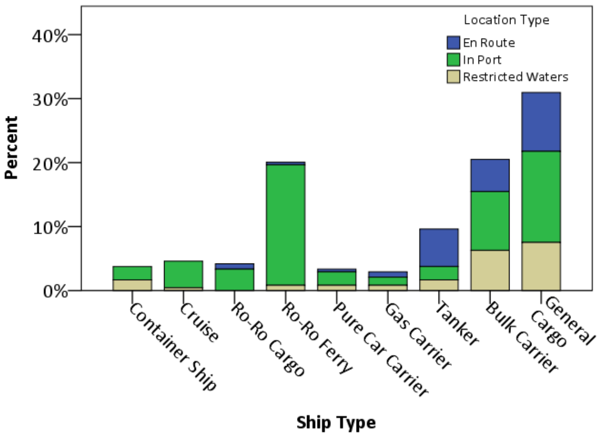


Figure 2. Percentage of ship types by accident location

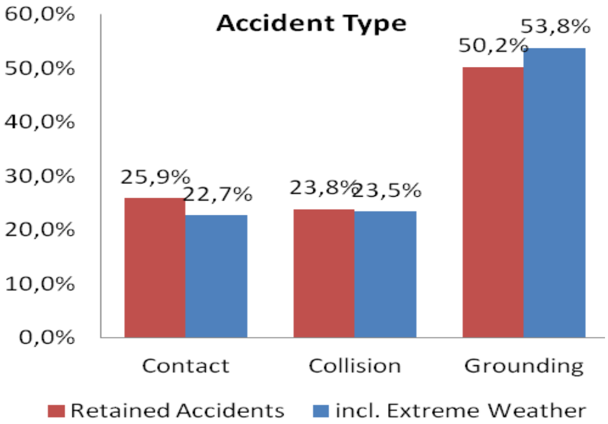


Figure 3. Comparison of distribution of accident types with included very extreme (abnormal) weather conditions

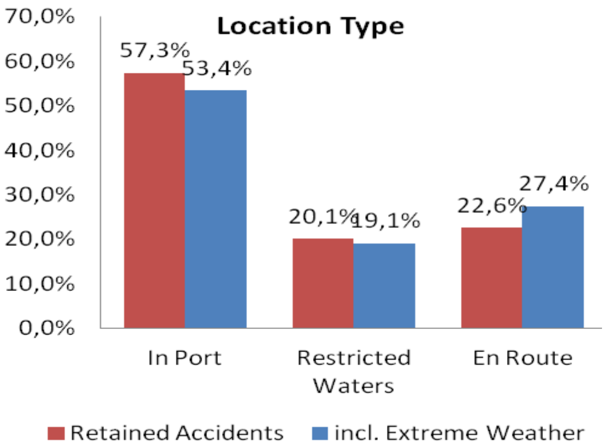


Figure 4. Comparison of accident location with included very extreme (abnormal) weather conditions

In view of the above findings, we consider three groups of criteria:

1. Manoeuvring in extreme conditions in open sea
2. Manoeuvring in coastal areas in a growing storm
3. Low-speed manoeuvring in wind and current in restricted waters

5. Manoeuvrability in Extreme Conditions in Open Sea

In the open sea, the ship must be able to turn into a favourable heading towards the seaway to limit excessive ship motions and to maintain this heading. Arguably, even uncontrolled drifting with waves and wind may be acceptable for some time. For container ships with low metacentric height, this practice is considered as one of the safest ways to weather-vane, if there is enough room available for drifting. Anyway, if the ship is forced to drift in beam waves and wind without being able to turn into seaway, her stability will be controlled by the Severe Wind and Rolling Criterion (Weather Criterion) [15].

However, is some situations it might be not acceptable for a ship to simply drift away without possibility of weather-vaning, for example, in loading conditions with deck cargo and large initial GM, because direct exposure to resonance roll excitation can lead to large lateral accelerations, loss or damage of cargo or even to injuries to the crew, or to water on deck for vessels with low freeboard. Another argument for the need to norm weather-vaning ability in extreme conditions is the preservation of the present safety level: the present rate of intact stability failures in dead ship condition is low because, first, combinations of extreme weather and engine failure are rare and, second, the Weather Criterion is sufficiently conservative. If, however, majority of ships would be uncontrollable in extreme weather due to reduced installed power (as a possible consequence of reducing EEDI), *the level of safety provided by the Weather Criterion alone might become insufficient*.

A counterargument to this reasoning, related to seakeeping and stability problems, can be in the way of adopting other design measures, not concerning manoeuvrability in extreme seaway; for example, adjusting the strictness level of the Weather Criterion, which will inherently lead to more severe seakeeping criteria, likely increase of required roll damping, stronger deck cargo securing etc.

If a criterion for manoeuvrability in extreme open sea weather conditions is required, the following is proposed: *the ship should be able to keep heading in head to bow-quartering extreme*[2] *waves and wind up to 60° off-bow to avoid synchronous rolling and water on deck.* Testing and adjustment of this criterion is required, as well as the definition of the “extreme weather” conditions. For the latter, benchmarking of existing ships against the proposed criterion, as well as accident investigations seem as possible way ahead and are planned within project SHOPERA.

6. Manoeuvrability in Escalating Storm in Coastal Areas

Operation in coastal areas places greater requirements on manoeuvrability than in the open sea: the ship must be able to change the course to the required one and maintain it; she should also maintain some minimum advance speed to leave the coastal area before the storm escalates. Because of possible navigational restrictions, all this must be possible in waves, wind and possible currents from any direction.

If a ship *can keep* any course with respect to the seaway, including seaway directions which are most unfavorable with respect to course-keeping, the ship will also be *able to perform any course change*. Thus, the requirement *to keep any course is more stringent than the requirement to change course*. However, course changing must happen in a short enough time, thus the requirement of some minimum advance speed in seaway from any direction is also necessary. The requirement of some minimum advance speed is also necessary to enable leaving coastal area before the storm escalates.

[2] The severity level of extreme weather conditions is arguable, considering that the ship may nowadays avoid crossing through violent weather conditions (hurricanes, typhoons etc.) and should by design and operation remain a cost effective transportation vehicle

These considerations led, during the work of IACS on minimum power requirements [3,4], to the following criteria:

- *ship must be able to keep any prescribed course in waves and wind from any direction*
- *ship must be able to keep advance speed of at least 4.0 knots in waves and wind from any direction*

Note that the use of port tugs in such situations is unlikely, because port tugs may not be available away from ports, and because port tugs cannot operate in heavy seaway; open sea tugs are used seldom in normal operations.

Whereas the compliance with the IMO Manoeuvrability Standards [7] is demonstrated in full-scale trials, evaluation of criteria concerning adverse weather conditions is impracticable in full-scale trials. Alternatives to full scale tests are model experiments and numerical computations. Because the assessment procedure will be routinely used by designers and verified by Administrations, it must be reasonably simple, inexpensive, transparent and verifiable. Ideally, the procedure should allow using both calculations and equivalent model tests interchangeably and complementarily, in such a way that any assessment can be verified, if necessary; this is only possible if experiments and computations are performed in simple and well-controlled conditions.

In principle, evaluation of the course-keeping and advance speed criteria requires transient model tests with self-propelled models in simulated irregular waves and wind, for all possible wave and wind directions with respect to the ship course. Such experimental techniques are however not mature enough; besides, few facilities exist worldwide able to carry out such tests, which makes them impracticable for routine ship design and approval. Further, reliable predictions in irregular seaways require repetition of tests in multiple realisations of the same seaway in a seakeeping basin, Fig. 5, which is expensive. Finally, the time history of the applied helm in each seaway realization is deciding for the results, and impact of its variability is difficult to quantify, especially for regulatory purposes. Despite some progress in the State of the Art, available numerical methods for the simulation of transient ship manoeuvres in waves are still not mature enough for routine use in ship design and approval.

Figure 5. MARINTEK's 80mx50m Ocean Basin facility (project SHOPERA)

Therefore, a practical assessment procedure should be based on *steady model tests or calculations, under well-controlled conditions*. A possible simplification is to neglect oscillatory wave forces and moments because their time scale is shorter than the time scale of manoeuvring motions, and thus to consider only average in time forces, moments and other variables, such as propeller thrust, torque and rotation rate, required and available power, drift angle and rudder angle. The second possible simplification is to use spectral methods to calculate wave drift forces and moments, which requires only measurements or calculations of drift forces in regular waves. Encounter-frequency wave-induced motions and forces can influence manoeuvring, especially in high waves, in several ways:

- At high speeds in stern waves, encounter frequency motions can induce broaching-to; however, broaching-to can be handled in operation (speed reduction) and is, moreover, not relevant to minimum power requirements.
- Neglecting oscillations of propeller thrust, of required and available power and jumps of the required power above the torque-speed limit

(engine overload) due to encounter-frequency motions and forces, we introduce a non-conservative error. This error is to some degree compensated by the conservativeness of the course-keeping requirement in any wave and wind direction; besides, short overload is possible without damage to the engine.

- Propeller pitching reduces available time-average thrust; besides, it leads to the drop of the mean available power due to dynamic response of a diesel engine after ventilation events and can even lead to engine shutdown. These effects are particularly relevant in ballast loading conditions and can be ignored if the assessment is done for full load condition, not extreme seaways and at low forward speeds.
- Rudder is used in seaway both to ensure course-keeping with respect to the steady effects and to compensate the dynamic yaw motions due to waves and wind gusts. To take these dynamic effects into account in the procedure, the maximum available average rudder angle should be slightly lower than the maximum possible rudder angle (by 3-5° to 10° according to different sources).

Any practical procedure inevitably involves simplifications, each of which leads to either conservative or non-conservative bias. The overall safety level as an outcome of the adopted assessment procedure can still be fine-tuned by the adjustment of the standards: in this case, the environmental conditions used in the assessment should lead to an appropriate classification of existing ships into safe and unsafe. The only trivial requirement to the procedure is that it should be sensitive to ship-specific factors, which are important for the manoeuvring in waves.

One of important ship-specific factors in this respect is the under way drift motion: in response to seaway-induced lateral forces and yaw moment, the ship will sail at a certain average drift angle and with average rudder angle; this increases the required propeller thrust and the required power. Thus, the assessment procedure should take into account at least three degrees of freedom (horizontal motions and yaw); the hydrodynamic problem may be then solved as a steady equilibrium problem in the horizontal plane for the ship advancing with constant forward speed and course under the action of average wave and wind forces, calm-water drift forces and rudder and propeller forces. The solution of the system of equations provides the required average propeller thrust, drift angle and rudder angle. From the propeller thrust, average advance ratio and rotation rate of the propeller are found using open-water propeller curves; then the average in time required power is calculated, as well as the average available power (which will be less than MCR due to reduced rotation rate in seaway). The procedure takes into account longitudinal and lateral forces and yaw moments due to

- *Wind*: can be defined from wind tunnel tests, RANSE simulations or empirical data
- *Waves*: seakeeping tests in regular waves, perhaps potential flow computations or empirical formulae
- *Calm-water*: steady model tests, RANSE simulations, empirical data or formulae
- *Rudder*: steady model tests, RANSE simulations, semi-empirical models
- *Propeller* (open-water propeller curves): steady model tests, propeller series, potential or RANSE computations

The procedure checks whether the required average rudder angle is less than the maximum allowed rudder angle (taking into account margin for steering in waves) and whether the average required power does not exceed the average available power. Example of assessment results in Fig. 6 shows in axes ship speed (radial coordinate) – wave and wind direction (circumferential coordinate) achievable operational conditions (grey area) in waves with significant wave height 6.0 m; in this example, the ship can fulfill the course-keeping criterion with the installed engine and rudder, but fails to keep advance speed of 4.0 knots in waves and wind from directions against the course to about 60 degree off the course.

The advantage of this procedure is that the time-average forces and moments due to different factors (wind, waves, calm water, rudder and propeller) can be computed or measured separately, in simple well-controlled steady tests, and combined in a simple steady mathematical model. If necessary, separate force components can be verified in additional model tests.

Several observations can be made regarding environmental conditions to be used with these course-keeping and advance speed criteria.

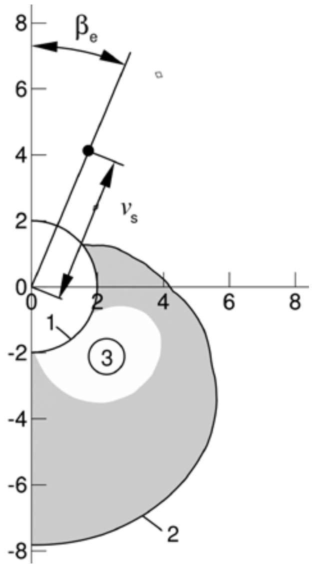


Figure 6. Example of assessment results for a handysize bulk carrier for significant wave height 6.0 m: line 1 – advance speed of 4.0 knots, line 2 – required power equal to available power, area 3 – rudder angle greater than 25°, v_s is ship speed, β_e is wave and wind direction (ship course is to the north)

First, these conditions cannot be too severe because ships usually leave to the open sea or search for a shelter before storm escalates. Second, although ship masters know the capabilities of their ships and, if weather forecast is available, they can decide when they have to search for shelter or leave to the open sea, practice shows that in the majority of accidents, ships wait at anchor in a growing storm and thus, anchor dragging defines very frequently the environmental conditions for leaving coastal areas in practice. Figure 7 shows the dependency of the number of ships remaining at anchor as percentage of the initial number of vessels at anchor vs. significant wave height during an increasing storm, based on data [13].

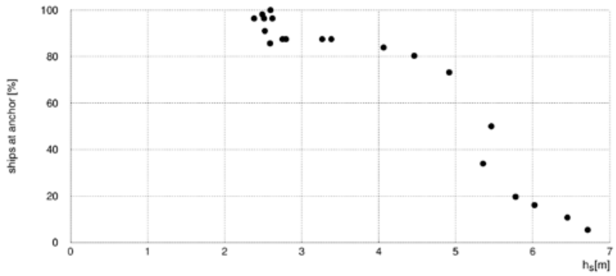


Figure 7. Number of vessels at anchor as percentage of the initial number of vessels vs. significant wave height during an increasing storm according to data in [13]

About 80% of vessels were still at anchor at the significant wave height of 4.5 m, whereas at 6.0 m, the majority of vessels have already left to the open sea only about 20% remained at the anchor. In this case, all vessels left anchorage only after they have dragged anchor in the increasing storm. An argument against using the anchor holding power to define the environmental conditions for leaving to the open sea is the fact that anchoring equipment is intended for temporary mooring of a vessel, and not designed to hold the vessels off exposed coast in rough weather, even though in practice this is frequently the case.

Another consideration is the idea to use statistics of *environmental conditions during groundings, contacts and collisions*; a similar approach was used to choose the wave height for the definition of survival probability in the SOLAS damage stability requirements. According to the results of HARDER project, concerning statistics of weather conditions at the time of *collision* for all ship types, Fig. 8, 80% of collisions happened at significant wave heights below 1 m, i.e. practically in calm water, and very few accidents happen at significant wave heights in excess of 4 m.

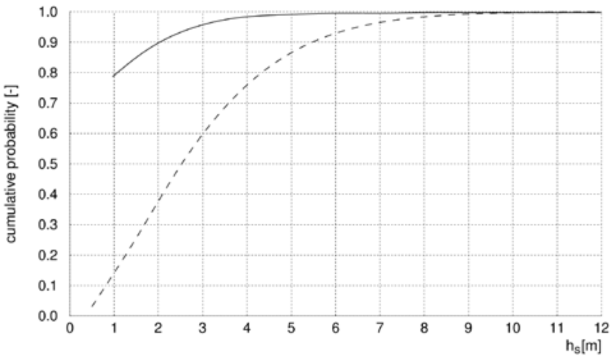


Figure 8. Cumulative probability of significant wave height during collisions according to HARDER database (—) in comparison with North Atlantics wave climate (- - -)

Note that Figures 1-4 from the SHOPERA project [14] show that adverse environmental conditions are more relevant for contact, grounding and stranding accidents than for collisions; the corresponding statistics of environmental conditions is to be evaluated yet.

As final consideration, a practical approach to the definition of environmental conditions to be used in the assessment is the benchmarking of existing ships against the new criteria; the advantage of this approach is the possibility to calibrate the assessment procedure and thus compensate for all biases due to inevitable simplifications. Such an approach, which relied on the assumption that only a small percentage of existing vessels in service might have insufficient manoeuvrability in adverse weather conditions, led to the following environmental conditions in [5]: significant wave height 4.0 to 5.5 m for ships with length between perpendiculars less than 200 and more than 250 m, respectively, and corresponding wind speeds of 15.7 to 19.0 m/s, respectively; modal wave periods vary from 7 to 15 s in all cases. The reduction of significant wave height to 4.0 m for small vessels followed from applying the course-keeping and advance speed criteria to small (about 20000 t dwt) bulk carriers and tankers.

7. Low-Speed Manoeuvrability in Wind

Manoeuvrability at low forward speed in strong wind is critical for ships with large windage area, such as container ships, cruise vessels, RoPax and car carriers, during approach to and entering ports (where also strong current is frequently relevant). There are several specific considerations in this respect. First, low-speed manoeuvrability does not seem to be an issue of safety for most ship types, but an operational issue: because these criteria concern port entrance, availability of port tugs can be assumed. Some vessels are towed during the complete port entry, so they might not need low-speed manoeuvrability[3]. Second, such criteria will lead to additional requirements on the steering performance, but not to restrictions on the minimum installed power, thus there is no potential conflict with EEDI. Still, these criteria are considered in the project SHOPERA for completeness. According to proposals in the literature, the following criteria seem to be suitable:

- *course-keeping in strong wind at specified reduced speed in loading condition maximizing lateral windage area*
- *course-keeping in shallow water near channel wall or bank at specified reduced speed in load case maximizing hydrodynamic forces*
- *course-keeping on shallow water at reduced forward speed during overtaking by a quicker ship in load case maximizing hydrodynamic forces*

In these criteria, no waves are considered but strong wind and, perhaps, strong current. In addition to steering devices dimensioning, these criteria provide important guidance to operators, e.g. up to what speed the ship can manoeuvre itself in a given wind and beyond what wind force tug assistance is required.

Low-speed manoeuvrability criteria require specification of the wind speed and, perhaps, current. Reference [8] recommends wind speed of 20 knots for general use and 30 knots for ferries and cruise ships, as the wind speed at which the ship should be able to leave the quay.

[3] Important exemption to this rule are RoPax and passenger ships in general, commonly not calling for tug assistance; the insufficiency of tugs in small ports should also be considered.

8. Way Ahead to Fill Gaps

Most of the *accident reports* studied so far [14] are from the IHS Sea-Web Marine Casualty Database and the public area of Marine Casualties and Incidents Database of the IMO Global Integrated Shipping Information System (GISIS). Information collected from these sources was cross-referenced, whenever possible, with accident reports acquired from the following sources:

- Marine Accident Investigation Branch (MAIB), United Kingdom
- Swedish Maritime Safety Inspectorate
- Federal Bureau of Maritime Casualty Investigation, Germany
- Panama Maritime Authority
- Marine Accident Inquiry Agency (MAIA), Japan
- Transportation Safety Board of Canada
- Accident Investigation Board Norway (AIBN)
- Maritime Safety Authority of New Zealand
- Maritime Safety Investigation Unit, Malta

We believe that the collected data are sufficient to evaluate the risk of the operating worldwide fleet with respect to the maneuverability in adverse conditions.

Another activity is to complete initiated interviews with ship masters: so far, masters of about 30 container ships and about 5 bulk carriers were consulted. Thus, interviewing masters of RoPax and passenger ships, bulk carriers, tankers and especially general cargo vessels is an important activity to verify criteria and environmental conditions.

Finally, available statistics and accident reports show that adverse weather conditions in coastal areas are especially relevant for grounding and stranding accidents and for contacts with fixed installations. However, the only available processed statistical data on wave heights during accidents (HARDER database) concerns collisions, for which poor visibility in calm-water conditions is most relevant. Thus, statistics of environmental conditions relevant to grounding, stranding, and contact accidents is required to define environmental conditions for all three groups of criteria.

Development of Criteria: One of the main strengths of the IACS proposal [3,4] is the three-tiered approach, allowing better flexibility to designers and evaluators in meeting the requirements. The considerations presented in this paper concern only Level 3 procedures (*Comprehensive Assessment*). Note that in the final version of Guidelines [5], comprehensive assessment was dropped because of the insufficient state-of-the-art of numerical methods for the assessment to be used for regulatory purposes. Implementation of Level 3 procedures in the new Guidelines requires the following: first, three groups of criteria (for growing storm in coastal areas, extreme waves in the open sea and low-speed manoeuvring in wind) should be tested and updated as necessary; this especially concerns criteria and corresponding environmental conditions for extreme waves in the open sea. Second, the proposed simplifications in the assessment procedure should be validated and, if necessary, revised; transient simulations of course change in waves, taking into account first-order forces and other dynamic effects can be used for validation. Third, further simplifications of the proposed Level 3 procedure should be considered. Environmental conditions should be defined and justified for all three groups of criteria.

To develop Level 2 procedure (*Simplified Assessment*), a possible approach is to use empirical formulae for all forces and moments, including the horizontal wave drift forces and yaw wave drift moment. Level 1 assessment procedure is supposed to be simple and based on some empirical formulae or graphs, which are to be developed after processing results of application of the Level 3 procedure to a sufficiently large number of ships; this procedure should take into account installed power as well as steering and propulsion efficiency.

Numerical Methods: For the horizontal forces and yaw moment due to wind and calm-water motions, the existing SoA of numerical methods seems adequate. For a practical procedure, empirical data can be used for wind forces; for calm-water forces, such empirical recommendations exist for VLCCs but still have to be developed for other ship types. Also desirable is the development of validated semi-empirical models for rudder forces in propeller race; some existing models [16,17] can be used as a starting point and fine-tuned.

Problematic is the determination of the horizontal drift forces and drift yaw moment due to waves. For a practical procedure, their computation with potential theory panel methods is desired in the long-term, which requires development, fine-tuning and validation of such methods; in the short term, semi-empirical solutions can be an alternative.

Impact of New Manoeuvrability Standards: Because the proposed criteria address only the ability of ships to withstand environmental conditions, ships subject to the new criteria will also have to fulfill IMO Manoeuvrability Standards [7]. In this respect, it has to be checked how the reduction of installed power influences the fulfillment of the IMO Manoeuvrability Standards: it is well known that turning circle parameters (transfer and advance) are nearly identical for different engine sizes for the same rudder area (time scale of turning is of course different); however, zig-zag manoeuvres are affected by the reduction of the engine size, thus it is interesting to see to what degree reduced installed power will influence the ability of ships to fulfill the requirements of 10°/10° and, especially, 20°/20° zig-zag in calm water. Another important check is whether the existing fleet in service is evaluated in a feasible way by the new criteria; otherwise, criteria and environment will have to be adjusted.

Design and Optimisation: An important question for ship designers in the EEDI era will be to manage possible contradictions between EEDI requirements, especially in Phases 3 and 4 of EEDI implementation, and minimum power requirements (which will have to be based on the present navigational practice). An important task of SHOPERA is to elaborate on optimal design solutions, demonstrate their feasibility and assess them through case studies involving multiple criteria. There may be the possibility to employ emergency means of manoeuvring and propulsion, e.g. emergency rating of the engine, which should not be used for propulsion in normal operation and thus not included in the EEDI calculation, and should be only activated in adverse weather conditions.

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