DISCUSSION

PROBABILISTIC SAFETY OF ESTUARY VESSELS BASED ON NONLINEAR ROLLING IN WIND AND WAVES

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COMMENT

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In the first place the discusser would like to congratulate Dr. Bačkalov with his paper, in which he assesses the new Belgian safety regulations for estuary vessels by means of a non-linear approach taking account the effect of a combination of beam waves and unsteady beam wind. The results presented are based on a solid, scientific background, and the author's approach as published in former papers can be considered as the base of a promising methodology for evaluating the stability and safety of a vessel in waves and wind. As the discusser has supported the Belgian federal authorities in defining the methodology and formulating the present regulations, it is a pleasure to learn that the implementation of the latter is considered as a significant step in the general improvement of ship safety regulations.

The author mentions that the present Belgian regulation [14] for estuary vessels (officially called "vessels for inland navigation also used for non-international sea voyages") introduce some "doubtful approximations", due to the fact that the effects of gusting wind are omitted in the seakeeping calculations and are covered in a deterministic way, and due to the use of linear equations of motion. However, the very representative example demonstrates that in the typical conditions valid in the Belgian coastal area, these simplifications have a nearly negligible effect and appear to be justified in the local context. On the other hand, it is concluded that a general application of the methodology should account for wind gustiness and nonlinearities.

In spite of the simplifications mentioned above, it could be stated that the Belgian regulations are in several ways more general in their approach, as the risk analysis that has to be performed for each individual estuary vessel not only takes account of the probability of occurrence of reaching a critical roll angle, but also concerns avoidance of slamming, green seas and shipping of water on deck or, for open hatch container vessels, in the cargo holds. For investigating these effects, all relevant degrees of freedom (pitch, heave and roll) have to be considered. In all studies performed so far, the roll criterion has never been the most critical one; instead, the required margins for shipping of water on deck or in the cargo holds at the most forward points appear to be more severe.

In order to obtain a realistic estimation of the ship's behaviour in the local wave conditions, the selection of wave spectra is of great importance. In fact, the way the author describes this selection is not completely correct. According to the Belgian regulations, the ship's response must be calculated in wave conditions that can realistically be regarded as representative of the restricted sea area. The study must use relevant directional wave spectra drawn up on the basis of the frequency and direction analysis of observed wave diagrams. It must be based on a determination of the ship's response to all spectra observed over a period of one year. The reference period is determined in consultation with the official responsible for shipping monitoring appointed for this purpose. In practice, the response of the vessel is calculated to all spectra that are observed by a local directional wave buoy in a full year's time with a 30 minutes interval, i.e. to 17520 directional spectra. In this way, the local wave climate and the spreading of wave energy in frequency and direction is fully taken into account. Making use of a linear approach, the time required for these calculations is still acceptable, but the use of non-linear techniques would require a (much more time consuming) time domain approach.

Wind effects are, as mentioned, not explicitly taken into account in the Belgian regulations. Their importance is clearly illustrated by Dr. Bačkalov, but it should be borne in mind that navigation of even sea-going vessels to the port of Zeebrugge and the Western Scheldt estuary is mostly stopped at approximately Beaufort 7 (14-17 m/s), and, in particular, no estuary ships will ever obtain a permission to leave the harbour or the Western Scheldt in such wind conditions. The graphs in the paper show that in this range the effect of wind is rather limited.

The paper clearly illustrates the importance of the metacentric height. This parameter is not mentioned explicitly in [14], but in practice the risk analysis is performed for a realistic range of GM values, referring to the requirement that the calculation of the RAOs should be based on a realistic weight distribution of unladen weight and cargo throughout the ship. The calculations confirm the author's conclusions: the exceedance probability increases (or the allowable significant wave height decreases) with increasing GM, so that the metacentric height must not exceed a maximum value [15]. The certificate issued by the Belgian federal authorities therefore always mentions a range of GM values for which operations at sea are allowed.

In his conclusions, the author mentions the advantages of (commercial) seakeeping software that properly accounts for gusty wind effects as well, to be used as an on-board tool supporting the master of an (estuary) vessel in his decisions. Such an approach is not explicitly foreseen in the present Belgian regulations; however, it could be part of the required assessment procedure for deciding whether or not to start a sea voyage, if the method were to cover all other criteria as well. The availability of reliable and accurate measurements and short-term predictions of relevant meteorological data is of great importance in this respect.

Finally, the discusser would like to emphasize the importance of research leading to a deeper insight into the sensitivity of the final safety of a sea voyage to all relevant parameters defining the loading condition of the ship and the environmental conditions. After two years of experience with estuary container vessels in the Belgian coastal area, some ship owners and operators have expressed their interest in a more flexible admission policy, e.g. by making the allowable draft dependent on the actual wave height, so that it would be possible to take more cargo in favourable sea states. However, a more flexible policy should never jeopardize safety, and can only be granted if all threats can be assessed properly. For this reason, Dr. Bačkalov's research is highly appreciated.

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The author correctly points that the classical seakeeping approach as applied to ship rolling in Belgian Standards for Estuary Vessels has two main deficiencies: it neglects motion nonlinearities and the influences of wind. The author's numerical analysis proved that the nonlinearities are of no great importance for estuary vessels, because of small rolling amplitudes involved. It should be stressed, however, that such conclusion does not apply to typical seagoing ships, which could roll heavily in the beam waves. Concerning the wind, the author shows how this effect could be very significant at some metacentric heights. Correctly, he shows that the influences of wind increase as the metacentric height decreases, but does not explain in full this important result.

It is believed that Figure 10 explains more clearly the influence of metacentric height on ship safety imperiled by the wind and waves. It presents the probability that a small sea going containership (85mlong) would heel up to the angle of 50° in two hours under the influence of beam gusting wind of mean speed 26m/s and the corresponding irregular beam waves of significant height 11m. The results are obtained by a very similar technique as used in the commented paper, and the value 10^{-3} was accepted as the maximal allowable probability of heel. The results demonstrate how, at small metacentric heights, the wind effect is dominant and the wave effect negligible. At large metacentric heights the situation is the opposite–so the wave influences dominate. In other words, at small GMs, the safety is mainly governed by the static heels due to wind, which increase with the decrease of metacentric height. At large GMs, the safety is mainly governed by the roll amplitudes due to waves, which increase with the increase of metacentric height. Only if both influences (wind and waves) are present, the probability curve has the typical saddle, giving the optimal metacentric height from the ship safety point of view.

Although the commented paper does not give the above clarification, the presented results do fit well into this general picture.

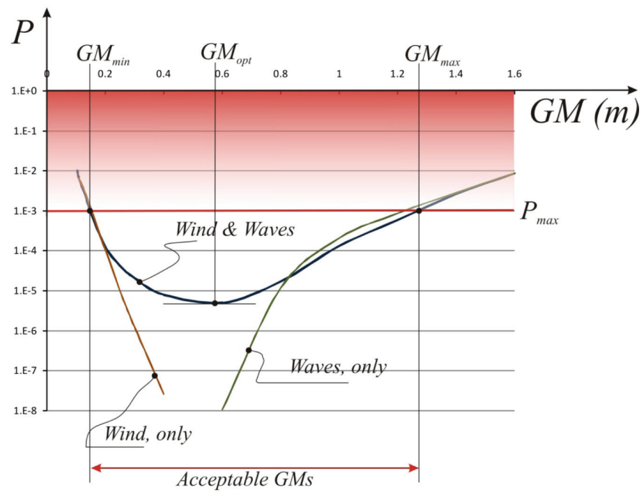

Figure 10. The probability that a small containership would heel up to 50^o in two hours, under the combined influence of beam gusting wind of mean speed 26m/s and the corresponding beam waves.

AUTHOR'S RESPONSE

The author would like to thank to the discussers for their valuable contributions. Both of the discussers also provided helpful comments in course of the research presented in the paper; these comments proved to be very important for better understanding of the estuary navigation.

As **Professor Vantorre** pointed out, the analysis presented in the paper was limited to a single aspect of the present Belgian regulations for estuary navigation [14] – the requirements and procedures related to roll motion – while in practice, the other aspects relevant to the safety of estuary vessels in seaway are taken into account as well. However, the author believes that the overall importance of the analyzed regulations is not primarily in the procedures used or motions and loads analyzed, but in their advanced probabilistic performance-based concept involving seakeeping calculations which was, for the first time, implemented in the rules concerned with intact stability (in waves). This significant step overcomes the local character of the regulations (both in terms of geographic scope and application field) and, in author's opinion, should set a general course in the development of future regulations.

Both the discussers notice that not only the minimal but also the maximal value of metacentric height can be determined as a requirement for safety of ships in realistic weather conditions. In addition, a curve similar to the one provided by **Professor Hofman**, may be plotted for the examined estuary vessel too, but for a different loading condition. Namely, the present regulations limit the maximal draught of an estuary vessel in the seaway. The "sea-going" draught corresponding to the sample vessel used in calculations is 3m; for such loading condition, it would not be realistic to attain smaller metacentric heights. Therefore, the influence of metacentric height on the safety in beam wind and waves could not be fully exhibited. However, if the probability of reaching critical roll angle is calculated for instance for the draught 3.8m, the said "saddle" curve defining the range of acceptable metacentric heights as well as the "optimal" GM may be obtained [Figure. 11].

It should be noted that the curves given in Figure 11 were obtained for weather conditions that are considered as extreme from the point of view of estuary navigation (above Beaufort 7), and that, as such, they fall out of scope of estuary traffic.

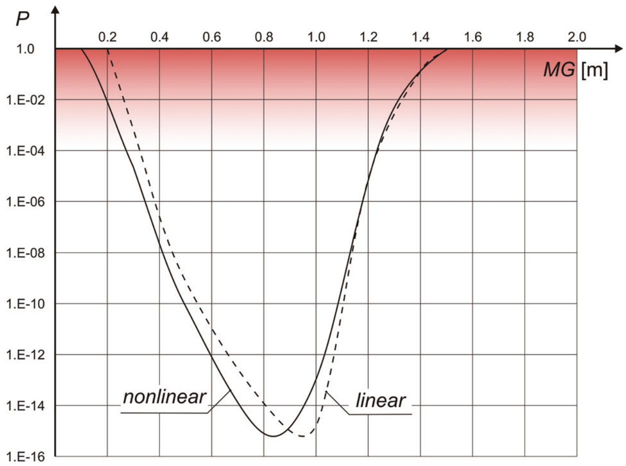

Figure 11. Probability of flooding vs. metacentric height

The author agrees with Professor Vantorre that nonlinear approach involves time-consuming calculations, especially if they are to be performed for as many as 17520 sea states. On the other hand, this may put forward the applicability of a nonlinear short-term approach related to an assumed scenario, in this case the beam wind and waves. Indeed, this and a number of other issues are the subject of the extensive research and discussion within maritime community, see e.g. [16]. The author hopes that this paper, the discussion that followed and (most of all) the practical experience with estuary navigation may contribute to the development of the future safety regulations.

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