On Safety of Inland Container Vessels Designed for Different Waterways

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In their previous investigation, the authors developed a new, risk-based method for the analysis of inland vessel safety, when exposed to the beam gusting wind. In the present paper, the method is used to analyze the behaviour of container vessels designed for different inland waterways. It shows that the risk of flooding due to beam wind increases with the decrease of vessel draught. Furthermore, it proves that the present safety regulations do not account this effect properly. The regulations are more appropriate for the vessels with large draughts (e.g. the Rhine vessels), while the vessels for shallower waterways (as the Danube) are put to the higher risk of the accidents. Finally, the authors propose the improvement of the present safety rules, which would account properly the conditions on the different inland waterways.

Keywords: *inland container vessels, risk-based safety analysis, nonlinear rolling, inland vessel safety regulations.*

1. INTRODUCTION

In the previous research [1-3], the authors developed new tools for investigation of safety of inland vessels subjected to the beam wind. Instead of the classical approach based on static and dynamic angle of heel due to steady wind, the novel approach accounts wind gusts from the corresponding wind spectrum, and solves the vessel rolling from appropriate equations of motions. Then, by statistical analysis of roll time history, the probability that the vessel would capsize, or heel to some permissible angle, was found. By comparing such risk-based analysis to the classical ship stability regulations, it was shown that the present stability rules for inland container vessels are not strict enough. Despite satisfying the present rules, the vessels could be flooded and eventually capsized, in some extreme but realistic circumstances.

The preceding investigation was focused on container vessels of minimal safety according to the present rules (minimal metacentric height, minimal freeboard, minimal safety distance). It involved numerous numerical experiments, in which the probability that the vessel's open container hold would be flooded by the action of beam gusting wind was calculated. Some of these numerical experiments indicated, strangely, that the probability of flooding depends on the vessel draught. If true, such result points to the inconsistency of the present safety rules: the container vessels complying with the rules, but designed for waterways of different water depth, would have different risk of accidents.

The present investigation, therefore, systematically examines the dependence of the risk of flooding due to beam gusting wind on vessel design draught. Typical European inland container vessels, all having the minimal safety according to the present rules, were analyzed by numerous numerical experiments, proving that the risk of flooding always increases with the decrease of vessel draught. The Rhine container vessels, having the draughts of over 3 m, would be therefore considerably safer than the lower Danube vessels, where the draught could not be over 2.1 m. It seems that the present rules have been based on conditions on the Rhine (where the container transport is intensive, and the tradition long), and have overlooked the problems of waterways with smaller water depth. Consequently, the Danube container vessels are put in potential danger. The expected rapid growth of the container transport on the Danube will only emphasize this problem in the oncoming years. The authors, therefore, propose appropriate improvements of the present inland container vessel stability rules intended to make the vessel safety independent of their draughts.

2. RISK-BASED ANALYSIS

In general, the risk-based analysis of ship safety is a two-phase approach. In the first step, the time history of vessel's rolling is obtained by solving differential equations of her motions. In the second phase, the probability that the vessel would reach some characteristic angle of heel is calculated from the statistical analysis of the roll time history.

In the present investigation, system of coupled nonlinear differential equations of vessel sway and roll, explained in detail in paper [3], is used

$$\left(D+m_{\eta}\right)\ddot{\eta}+m_{\eta\varphi}\ddot{\varphi}+N_{\eta}(\dot{\eta})+n_{\eta\varphi}\dot{\varphi}=F_{\mathrm{w}}\left(v_{\mathrm{w}}\right)-F_{\mathrm{r}},$$

$$\left(J_{x}+m_{\varphi}\right)\ddot{\varphi}+m_{\varphi\eta}\ddot{\eta}+N_{\varphi}\left(\dot{\varphi}\right)+N_{\varphi\eta}(\dot{\eta})+M_{\mathrm{st}}\left(\varphi\right)= =M_{\mathrm{w}}\left(v_{\mathrm{w}}\right)+M_{\mathrm{r}}. \quad (1)$$

The first two terms on the left hand side of both equations are inertial forces and moments. The next two terms represent damping forces and moments, with linear and nonlinear parts

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$$N_\eta(\dot\eta) = n_\eta \dot\eta + \frac{1}{2}\rho A_s c_s \dot\eta|\dot\eta|,$$

$$N_\varphi(\dot\varphi) = (n_\varphi + \mu)\dot\varphi + \beta\cdot\dot\varphi|\dot\varphi|,$$

$$N_{\varphi\eta} = n_{\varphi\eta}\cdot\dot\eta - \frac{1}{2}\rho A_s c_s l_s \cdot \dot\eta|\dot\eta|.$$

In the present investigation, following [3], all added masses m_η, m_φ, $m_{\eta\varphi}$ = $m_{\varphi\eta}$, and potential damping coefficients n_η, n_φ, $n_{\eta\varphi}$ = $n_{\varphi\eta}$ are obtained by the use of classical strip-theory technique. Linear and nonlinear parts of viscous roll damping μ, β, are obtained by Ikeda method (see [4]). The coefficient of nonlinear sway damping force is taken approximately, as a constant $c_s \approx 1.2$. The last (restoring) term on the left hand side of the second (roll) equation is righting moment

$$M_{st}(\varphi) = gD\cdot h(\varphi) = gD\left[h'(\varphi) + MG\sin\varphi\right],$$

where the additional moment lever is approximated, for each tested vessel, by an odd polynomial of the form

$$h'(\varphi) \approx \sum_{n=0}^{N} a_{2n+1}\varphi^{2n+1}.$$

The first terms on the right hand side of the (1) present side wind force and moment

$$F_w = \frac{1}{2}\rho_w A_w c_w \cdot v_w{}^2,$$

$$M_w = \frac{1}{2}\rho_w A_w c_w l_w \cdot v_w{}^2,$$

where apparent wind speed (wind speed relative to vessel) is

$$v_w(t) = \bar v_w + v'_w - \dot\eta.$$

Absolute mean wind speed $\bar v_w$ is taken from the present stability rules (e.g. $\bar v_w$ = 18 m/s for zone 2), while v'_w presents the gusting wind speed

$$v'_w(t) = \sum_{n=1}^{N} A_n \cos(\omega_n t + \alpha_n).$$

The amplitudes of gusting wind speed is obtained from wind spectrum

$$A_n = \sqrt{2S(\omega_n)\cdot d\omega}$$

where, as in the previous investigation, well known Davenport spectrum is used

$$S(\omega) = \frac{4K\cdot\bar v_w^2 X_D^2}{\omega\left(1+X_D^2\right)^{\frac{4}{3}}},\quad X_D = \frac{600\omega}{\pi\cdot\bar v_w}.$$

The last terms on the right hand side of (1) are (somewhat) artificial. They present side force and moment

$$F_r = \frac{1}{2}\rho A_s c_s \bar v^2,$$

$$M_r = \frac{1}{2}\rho A_s c_s l_s \bar v^2,$$

added to the equations to keep the vessel, exposed to the side wind, on her course. Namely, as explained in [3], the beam wind tends to drift the vessel out of her course by constant drift speed

$$\bar v_\eta = \frac{k}{1+k}\bar v_w \approx k\cdot\bar v_w,\quad k = \sqrt{\frac{\rho_a}{\rho}\frac{c_w A_w}{c_s A_s}}.$$

However, in realistic circumstances, vessel's master would not allow that, so would try to keep the vessel on course by the use of the rudder. To simulate (approximately) such course-keeping model, a constant force F_r and (an appropriate moment M_r) have to be embedded to equations of motion, where (as found by numerical experiments in [3]) the speed $\bar v$ should be taken a few percent larger than the free drift speed $\bar v_\eta$.

With all the coefficients for the particular vessel found, the system of equations of motion is solved numerically by Runge-Kutta method, and vessel roll and sway motion $\varphi(t)$, $\eta(t)$ obtained. By the statistical analysis of the roll time history (see e.g. [2]), the mean angle of roll $\bar\varphi$, and standard deviation s_φ due to beam gusting wind, are found. The probability that the vessel would heel to some prescribed angle ϕ is then:

$$P = 1 - \exp\left\{-N_c \exp\left[-\frac{1}{2}\left(\frac{\phi-\bar\varphi}{s_\varphi}\right)^2\right]\right\} \approx$$

$$\approx N_c \exp\left[-\frac{1}{2}\left(\frac{\phi-\bar\varphi}{s_\varphi}\right)^2\right].$$

This result enables the risk-based analysis of the ship safety in the beam storms. It makes possible to analyze, by numerical experiments, the risk of flooding, capsize etc., and to obtain its dependence on various vessel and environmental characteristics. As announced in the Introduction, it would be used here to find the correlation of the probability P to the vessel design draught.

3. SAMPLE VESSELS

Investigation was conducted on typical European inland container vessels, 110 m long and 11.4 m in beam, designed to carry TEU containers in 13 bays and 4 rows, Fig. 1. It was supposed that all the vessels are loaded with 5 container tiers, which is the very maximum that could be achieved with a careful vertical load distribution only (see [5]). The vessel draughts vary from 2.1 m up to 3.1 m. The minimal value is suitable for the transportation on the lower Danube, while the maximal value is suitable for the Rhine, so the vessels with those extreme values of draught would be termed (for the sake of clarity) the **Danube Vessel** and the **Rhine Vessel**, respectively. All the vessels have open cargo holds with no hatch covers, and the minimal freeboard of 0.6 m, as prescribed, for instance, by UNECE Regulations for open hold vessels operating in zone 2 (see [6]). It is supposed, however, that the vessel hatch coaming height can vary between the minimal value of 0.4 m (indirectly prescribed by the Rules [6]) and some (technically reasonable) maximum of 1.5 m. The changes in the hatch coaming height directly influence the flooding angle, and therefore significantly impact the vessel safety.

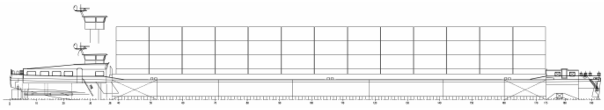

Figure 1. A typical European inland container vessel

Additional righting moment lever $h'(\varphi)$ for the Danube and the Rhine Vessel are presented in Figure 2. All the other vessels tested have their righting levers between these two extreme curves. In the calculations of roll damping, it was supposed that all the vessels sail with service speed of 16 km/h.

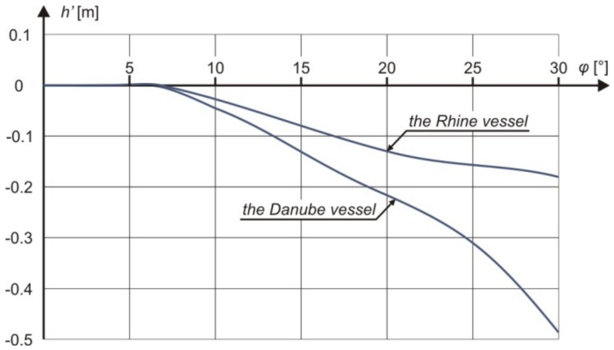

Figure 2. Additional stability levers of sample vessels

The following fact concerning the assumed container loading should be stressed. If the vessels, with fully utilized cargo space (number of TEUs fixed to maximal) and full cargo-weight capacities differ in draught, they would also differ in their displacement and the average mass of containers. The dependence of the average container mass on the draught can be found (see Fig. 3, taken from [5]), showing that the fully loaded container vessels designed for shallow waterways would be able to carry very light containers only.

It is believed that the series of standard 110 m × 11.4 m vessels selected for the numerical tests does represent the most suitable choice for the analysis of the influence of varying draught on the vessel safety.

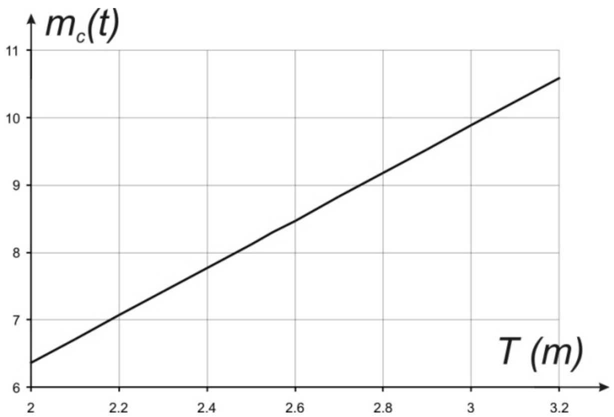

Figure 3. Average mass of container as a function of vessel draught (calculated for typical fully loaded container vessel, *L* = 110 m, *B* = 11.4 m, 5 tiers of containers [5])

4. NUMERICAL TESTS

The outlined procedure was used to calculate the probability that the vessel's open container hold would be flooded in two hours, under the action of gusting beam wind. The mean wind speed was supposed 18 m/s, as prescribed by most of inland stability rules for the vessels operating in zone 2. The terrene roughness was assumed 0.015, suitable for suburban areas. The permissible probability of flooding in the beam storm was accepted $P_a = \mathbf{O}(10^{-3})$, as discussed in detail in previous papers [1,2].

The obtained probabilities of flooding depend on three parameters: designed draught, hatch coaming height, and metacentric height. The design draught and hatch coaming height are the characteristics of the vessel, while the metacentric height depends on the loading conditions (or more precisely, on vertical position of centre of gravity). The results are, as in all previous investigations, presented and analyzed in the convenient form of (so called) probability curves $P = f(MG)$.

The probability curves for the Danube and the Rhine Vessels, for different hatch coaming heights, are presented in Figure 4. The region of unacceptable probabilities (too high risk of flooding) is shaded. As indicated earlier, the results show that the vessel of smaller draught would have higher risk of cargo hold flooding. More precisely, if

$$H_c \text{ (Danube Vessel)} = H_c \text{ (Rhine Vessel)}$$
$$MG \text{ (Danube Vessel)} = MG \text{ (Rhine Vessel)},$$

follows that

$$\text{P (Danube Vessel)} > \text{P (Rhine Vessel)}.$$

This is generally valid for any hatch coaming height. The quantitative difference of probabilistic results varies with metacentric height and hatch coaming height, and becomes in some cases substantial. For example, if H_c = 0.4 m and MG = 1.4 m, the probability of flooding of the Danube vessel is $\mathbf{O}(10^{-1})$, which is considered as unacceptably high risk. The corresponding probability of the Rhine vessel is $\mathbf{O}(10^{-4})$ indicated that these vessels, under the same conditions, are safe enough.

The impact of the design draught presented in Figure 4 could be expressed in a different way, also: inland vessels designed for operation in shallower waterway (the Danube) would obtain the same level of safety in beam storms as the vessels for deeper waterway (the Rhine) if their metacentric height is increased for some 20 – 30 cm.

The obtained result, showing that the container vessels of smaller draught are more vulnerable to the beam wind, could be physically explained. Namely, if the number of containers is fixed to maximal, the change of draught impacts the area exposed to wind, wind moment lever, and the vessel displacement. The results indicate that the prevailing effect is the change of displacement and, consequently, the change of vessel righting moment. The decreased draughts reduces the displacement, implying considerably smaller righting moment, with insignificant changes of exciting wind moment, only.

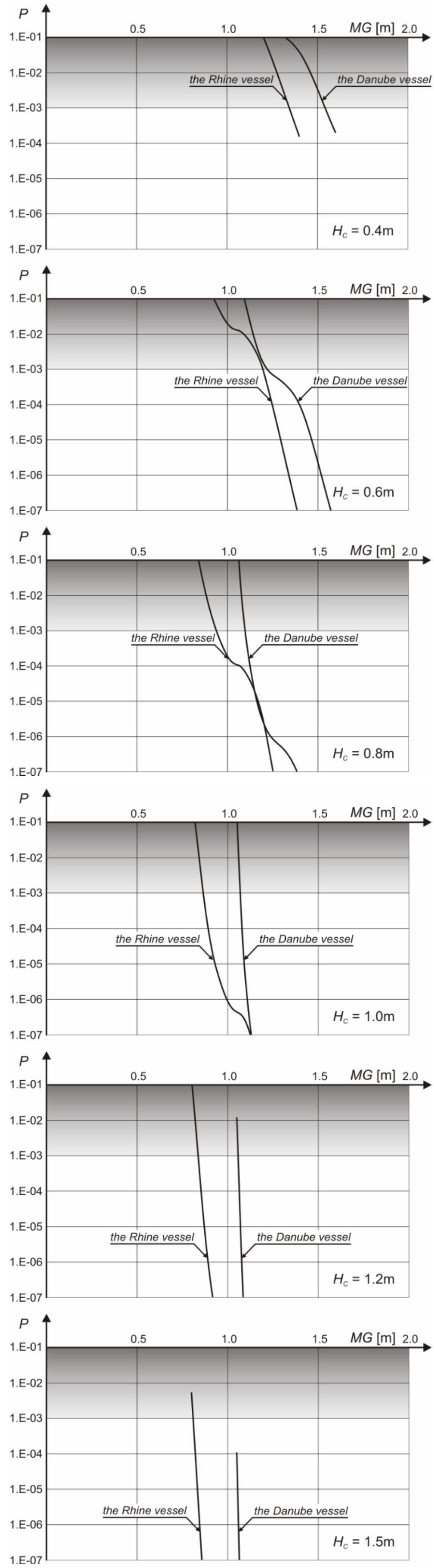

Figure 4. Probability curves of the sample vessels for different hatch coaming heights

4.1 Probabilistic analysis of stability regulations

The vulnerability of the vessels with smaller draughts, demonstrated in Figure 4, could have been (perhaps) assessed intuitively. The main question is, however, how the present stability regulations comply with that phenomenon. Are the rules for the shallow-draughted vessels stricter, so that the vessels of different draughts, complying with minimal stability requirements of the rules, would have the same risk of accidents?

In should be repeated that in the previous investigation [1-3], the inland container vessel stability regulations were found insufficient. It was demonstrated that these vessels, complying with the minimal stability requirements (minimal metacentric height, minimal freeboard and safety distance) could have unacceptably high risks of flooding. However, these investigations were carried out on vessels of 2.6 m draught (suitable e.g. for the middle Danube). How do the obtained disturbing aspects of present regulations apply to the vessels of higher and lower draughts?

As in [2] and [3], UNESCE Stability Rules [6] would be used as a typical representative of the present inland safety regulations. According to these rules, inland container vessel needs to fulfill some additional stability requirements besides basic ones that apply to all inland vessels. A container vessel should comply either with criteria of Method **A** (which is the same as stability criterion of ADN Rules [7]), or with those of Method **B**. Some of the principal features of Methods **A** and **B** will be just briefly accounted here, while the more extensive critical analysis of the Rules is given in [2].

Both methods, **A** and **B**, distinguish vessels carrying fixed and non-fixed containers. Both methods explicitly prescribe 1 m as minimal metacentric height for a vessel intended to carry non-fixed containers. In the case of fixed containers, however, the methods split: Method **A** sets 0.5 m as the minimal metacentric height, while Method **B** makes no similar explicit restraint, so the minimal metacentric height follows from the other rule demands (i.e. inland weather criterion, static wind-heel criterion, see [2]). The minimal metacentric height as function of vessel draught, calculated according to UNESCE Rules, Method **A** and **B**, for vessels carrying fixed and non-fixed containers, is presented in Figure 5. The other requirements of the Rules, affecting stability of vessels, include the minimal freeboard and (so called) minimal safety distance, implying that the open cargo hold vessels operating in zone 2 should fulfill the following conditions:

$$\text{Minimal freeboard } (F_B) > 0.6 \text{ m},$$

$$\text{Minimal safety distance } (F_B + H_c) > 1 \text{ m}.$$

As, for all the vessels tested, the freeboard is fixed to its minimal value, this requirement implicitly determines the minimal hatch coaming height as $H_c^{(min)} = 0.4$ m. It follows, in all the examined cases, that only the metacentric height for fixed containers – Method **A** is dependant on the vessel draught. All the other requirements are the same for all the vessels tested, regardless of their draught.

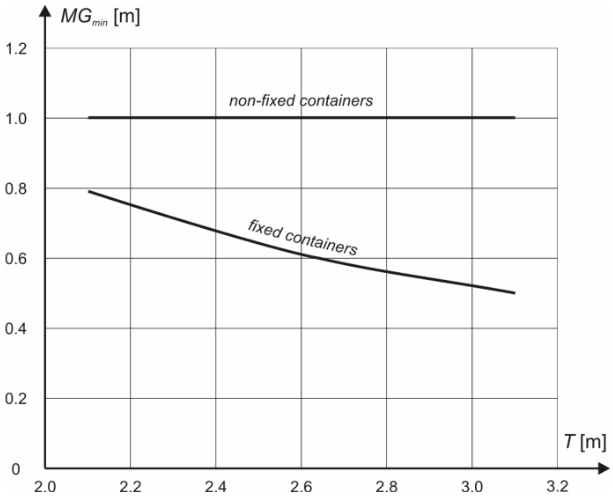

Figure 5. Minimal metacentric height for typical European inland container vessel (calculated according to UNECE Rules)

It is important to stress here the present practice in inland container transportation. The containers, at least in European inland waterways, are mainly carried as non-fixed. The hatch coamings on inland container vessels are (because of the structural requirements) in most cases over 1 m high, which is considerably higher than prescribed by the stability Rules. So, special attentions should be focused on such **custom vessels**, complying with those usual particularities.

The probability curves for the Rhine and the Danube vessels, for different hatch coaming heights, correlated to the minimal metacentric heights prescribed by the Rules, are presented in Figures 6 and 7. This comparison leads to several important conclusions.

The Rhine vessels are indeed safer in beam wind than the corresponding Danube vessels. **The custom Rhine vessels** (carrying non-fixed containers, having hatch coamings over 1 m high), **are safe enough** if their metacentric height is at the minimum prescribed by the Rules. However, if the hatch coaming height is at its very minimum (0.4 m), the metacentric height should be increased for more than 30 cm over the value prescribed by the Rules to get the acceptable probabilities of flooding. In the case of fixed containers, the situation is even worse. The metacentric height of the Rhine vessels, in this case, should be increased for at least 30 cm above the value required by the Rules, for **any** value of hatch coaming height.

The custom Danube vessels (carrying non-fixed containers, having the hatch coamings over 1 m high), **are not safe enough** if their metacentric height is at the minimum prescribed by the Rules. Even more, the Danube vessel cannot be made safe enough for any hatch coaming height if her metacentric height is at the minimum prescribed by the Rules. This implies for both cases: fixed and non-fixed containers, although the situation in the case of non-fixed containers is considerably better. The custom Danube vessels could be made safe enough if their minimal metacentric height is increased for some 10 cm.

Figure 8 presents the probability of flooding as a function of vessel draught for different metacentric height and for the very minimal hatch coaming height of 0.4 m. It shows clearly the unacceptability of such low hatch coamings, in spite of the fact that the Rules allow them. To reach the proper probabilities of flooding, the vessels of all draughts would have to have very large metacentric heights, much above the Rule minimum. Fortunately, as stated previously, such low hatch coamings are not used in practice, because of the other requirements. And that fact (as stated in [2]) seems to be the main reason for the absence of inland container ship accidents in the beam winds.

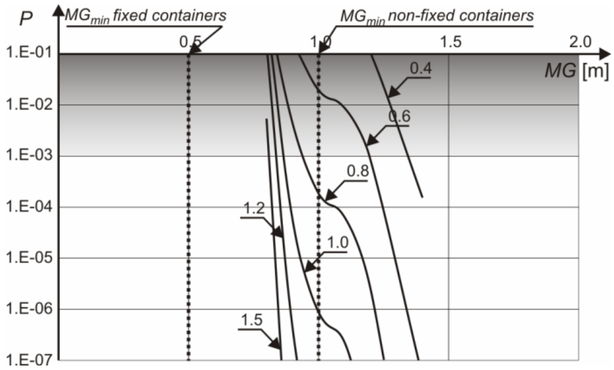

Figure 6. The Rhine vessel: probability curves for different hatch coaming heights correlated to Rule minimal metacentric height

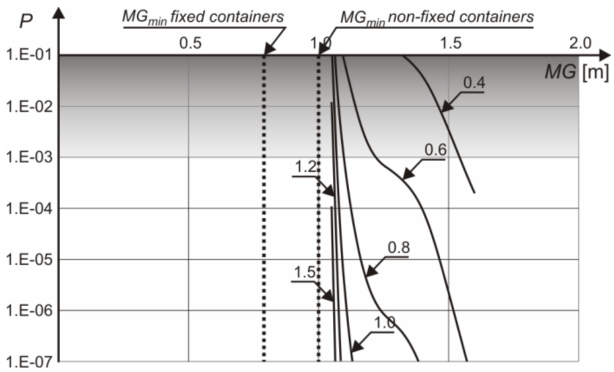

Figure 7. The Danube vessel: probability curves for different hatch coaming heights correlated or Rule minimal metacentric height

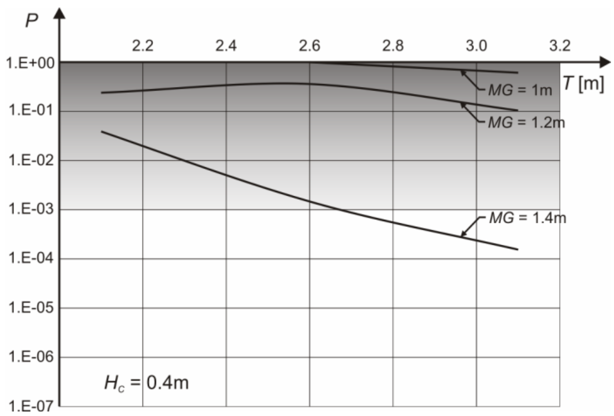

Figure 8. The probability of flooding in the beam wind for H_c = 0.4 m, and different metacentric heights

Figure 9 presents the probability of flooding as a function of vessel draught for different hatch coaming heights and constant value of metacentric height. The metacentric height is fixed to 1 m, as the minimal value for common case of non-fixed containers. It proves that the vessels of minimal hatch coaming height of 0.4 m are extremly unsafe. The figure also shows that the custom vessels, having hatch coaming height over a meter, are safe enough if their draught is over 2.5 m. The Danube vessels of small draught, however, could not reach the desired safety with any technically applicable hatch coaming height.

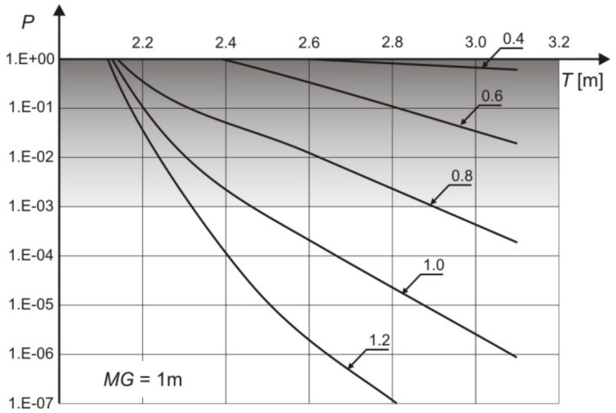

Figure 9. The probability of flooding in beam wind for *MG* = 1 m and different hatch coaming heights

5. CONCLUSIONS

A series of inland container vessels of the same length and breadth, loaded with the same (maximal) number of containers, but varying in draught, were exposed to the beam gusting wind of the mean speed prescribed by the stability rules. The nonlinear rolling of the vessel due to wind gusts was calculated and from these results the probability that the open container hold would be flooded was found. It was demonstrated that in such conditions the vessels of smaller draught would always have the higher risks of flooding.

It was found in the previous investigation [1-3] that the existing inland container vessel stability regulations are not strict enough, so that the vessel complying with the minimal rule requirements, have too high risks of flooding in the beam wind. In addition to that disturbing aspect of the rules, the present investigation demonstrated that the rules do not account properly the changes in the vessel draught. The decrease of draught, for the vessel complying with the minimal stability requirements, always implies the increased risk of flooding and eventual capsizing.

The earlier investigation indicated that the main reason for the lack of accidents connected to the insufficiency of regulations is the fact that the usual (custom) vessels, because of the structural (and other) requirements, do have hatch coamings considerably higher than prescribed by the rules. The present investigation pointed that such custom vessels (having hatch coaming heights of over a meter) are safe enough if their design draught is over 3 m, as usual on the Rhine. However, for draughts of 2.1 m (as restricted on the Lower Danube), the vessels of custom hatch coaming heights would have unacceptably high risks of flooding.

It seems that the present inland container vessel stability regulations have been tailored for the Rhine vessels of higher draughts and, therefore, do not account properly the vessels of smaller draughts, suitable for the Danube. The container transport on the Rhine has a long tradition and great importance for the Western Europe, so it is natural that the conditions on the Rhine were taken as a starting point for the rule development. However, the shortcomings of the rules concerning small-draughted vessels could provoke a tragedy, especially as is expected that the container transport on the Danube (for the reasons not to be elaborated here) increases rapidly in the oncoming years. Therefore, the authors appeal to the appropriate authorities to reconsider the rules and overcome the pointed shortcomings.

The obvious way to overcome the deficiency of the rules, and to make the risks of flooding and capsize of small-draughted vessels (at least) as low as of the Rhine vessels, is to prescribe the minimal requirements of the rules (minimal metacentric height, minimal safety distance) dependant on the vessel draught. The present investigation indicates that the minimal metacentric height of the Danube vessels should be increased for at least 10 cm. However, to make vessels of all draughts (for the usual case of non-fixed containers) safe enough from the probabilistic point of view, the requirement of minimal hatch coaming height should not be left to the good practice of vessel designers. It should be considerably increased over the present minimal value, and fixed by the rules to at least 1 m.

The main task of the novel approach employed in the present investigation is the development of the new, risk-based ship safety standards. However, before this long-term goal is achieved, the method could be used in numerous other topics of ship safety. The present investigation seems to be a good demonstration of the ability of the method, when applied to improve the existing ship safety regulations.

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NOMENCLATURE

A_n	amplitude of gusting wind speed [m/s]
A_s	vessel underwater lateral area [m^2]
A_w	vessel lateral area exposed to wind [m^2]
B	vessel breadth [m]
c_s	water drag coefficient
c_w	air drag coefficient
D	displacement [t]
F_B	vessel freeboard [m]
F_r	"course-keeping" force [kN]
F_w	wind force [kN]
g	gravitational acceleration [m/s^2]
h	total stability lever [m]
h'	additional stability lever [m]
H_c	hatch coaming height [m]
J_x	moment of inertia for x axes [tm^2]
K	terrain roughness coefficient
L	vessel length [m]
m_c	average container mass [t]
MG	metacentric height [m]
MG_{min}	minimal metacentric height [m]
M_r	moment corresponding to F_r [kNm]
M_{st}	righting (stability) moment [kNm]
M_w	wind moment [kNm]
m_η	added mass of sway [t]
m_φ	added mass of roll [tm^2]
$m_{\varphi\eta}$	coupling added mass coefficient [tm]
N_c	number of cycles
N_η	sway damping force [kN]
N_φ	roll damping moment [kNm]
$N_{\varphi\eta}$	coupling damping force [kN]
n_η	sway linear damping coefficient [t/s]
$n_{\varphi\eta}$	coupling damping coefficient [tm/s]
P	probability
P_a	acceptable probability
S	wind spectrum [m^2/s]
s_φ	standard deviation of roll [rad]
t	time [s]
T	vessel draught [m]
v_w	apparent wind speed [m/s]
$\bar{v}_w$	absolute mean wind speed [m/s]
v'_w	wind speed fluctuations [m/s]
$\bar{v}_\eta$	constant drift speed [m/s]
x	longitudinal central axes
α_n	phase shift of n-th wind component
β	quadratic roll damping coefficient
ϕ	prescribed angle of heel [rad]
φ	roll angle, heel [rad, °]
$\bar{\varphi}$	mean value of roll [rad]
μ	linear roll damping coefficient
ρ	water density [t/m^3]
ρ_a	air density [t/m^3]
ω_n	frequency of n-th component [rad/s]

О СИГУРНОСТИ РЕЧНИХ КОНТЕЈНЕРСКИХ БРОДОВА ПРОЈЕКТОВАНИХ ЗА РЕЗЛИЧИТЕ ПЛОВНЕ ПУТЕВЕ

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У претходним истраживањима аутори су развили нов „пробабилистички“ метод анализе сигурности речних бродова изложених бочном олујном ветру. У овом раду метод се користи за анализу понашања речних контејнерских бродова пројектованих за различите пловне путеве. Показано је да ризик од заливања и наплављивања услед ваљања брода изазваног ударима бочног ветра расте са смањењем пројектованог газа брода. Даље, утврђено је да постојећи прописи не урачунавају овај ефекат исправно. Прописи боље одговарају бродовима с већим газом (какви су нпр. бродови на Рајни), док су бродови за плиће пловне путеве (какав је нпр. Дунав) изложени већем ризику од заливања. Коначно, аутори предлажу побољшање постојећих прописа о сигурности речних контејнерских бродова, како би се исправно урачунали различити услови пловидбе на унутрашњим пловним путевима.