CAPSIZING PROBABILITY OF FISHING BOAT IN RANDOM SEAS [1]

James P.Panjaitan [2] and Rosdianto [3]

Abstracts

Safety againts capsizing aspects are very important for the fishing boat cruising in seas, because the boat is small in size and very risk to operate in rough seas. This paper is interested in investigating the insight of capsize and the probability at capsizing by making use of matemathical model. Prediction method to calculate the critical wave hight leading to capsize for fishing boats are proposed. The simplified method to compute at the probability of capsizing are evaluated for fishing boat running with specified combination of heading angle and speed in random waves. Finally the computed result are discused for Padang Tonda's.

I. Introduction

Safety againts capsizing in extreem seas is one of the most fundamental requirement considered by marine technologist when desining a fishing boat. In the line of this requirement, it is expected to develop probabilistic stability assesment for the random response at the fishing boat to a random seas specified by wave spectrum. This paper attemps to make a practical method to calculate critical rolling leading to capsize and the probability of capsizing in a random sea.

The experimental observation suggest that the probability of capsize maybe related to the probability of the fishing boat encountering a wave group having the characteristics necessary to cause capsize. When a fishing boat navigating throught a regular following sea, she will experience periodic variation in its transverse stability and these variations will affect the roll motion of the boat[1]. An approximately similar phenomena might be expected if the boat encounters a wave group having sufficient regularity and steepness in random seas. The purpose at this paper is to investigate the insight of capsizing and the probability of capsize in seas by making use of matemathical simulation.

II. Methods

When a fishing boat is running with a constant speed (v) and heading angle (x) in regular seas of frequency (w), the encounter frequency (w_e) is given by :

$$\omega_e = \omega - \frac{\omega^2}{g} v \cos x \qquad (1)$$

and the non-dimensional form $\omega_e \sqrt{L/g}$ is

$$\omega_e \sqrt{L/g} = \sqrt{2\pi L/\lambda}\left[1 - \sqrt{2\pi L/\lambda}\, F_n \cos x\right] \qquad (2)$$

where L = fishing boat, λ = wave length, Fn = Froude number, g= gravitational acceleration

In general ship motion leading to capsize in severe astern seas in nonlinear and complicated phenomena up to six degree of freedom [4]. However, the essential features of the capsizing phenomenion come from the variation of righting arm GZ dependent on the longitudinal position of fishing boat to waves [5]. In this condition the righting arm GZ fluctuates with respect to not only the rolling angle put also heave and pitch angle in the exact position of fishing boat to waves.

Therefore, the rolling angle ϕ (t) of the fishing boat will be described by combination of roll heave and pitch motion as

Roll :

$$(I_x + J_x)\phi + K_\phi \phi + \omega GZ(\phi, t) = K(t)$$

Heave : $$\rho g \int_L A(x,t)dx + Z(t) = mg$$

Pitch : $$\rho g \int_L XA(x,t) + M(t) = 0$$

Where Ix + Jx is the moment and added moment of inertia, K_ϕ the roll damping coefficient. W = fishing boat weight, GZ (ϕ,t) time dependent righting arm, Z(t). K(t) and M(t) are the heaving force, rolling and pitching moments acting on the instantaneous submerged hull. A(x.t) the instantaneous submerged sectional area which is also a function of heave $\Im_6$ and pitch Θ, as shown in fig. 2. m the fishing boat mass, g the graviting accellaration and ρ fluid density. The sea surface elevation $\Im_\omega(t,x,y)$ is

$$\xi_\omega(t,x,y) = -\xi_G + x\theta + \sum_{n=1}^{N} Cn \cos\left[\begin{array}{l} \frac{\omega_n^2}{g}(\xi_G + x\cos\chi - y\sin\chi\cos\phi \\ + Z\sin\chi\sin\phi) - (\omega_n - \frac{\omega_n^2}{g} v\cos\chi) \\ t + \varepsilon_n \end{array}\right]$$

Where N is the number of component wave, ω_n the circular frequency of n – th wave, ε_n random phase angle.χ the leading angle of fishing boat to waves, ξ_G the initial position of fishing boat navigating with speed U, Cn the amplitude of the n – th wave given by the power spection S(ω) as

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[2] Laboratory of Fishing Boat and Navigaton System, Faculty of Fisheries and Marine Science, Bogor Agricultural University (IPB), Bogor, West Java-Indonesia

[3] Postgraduate Student at Lab. Of Fishing boat and Navigation System, Faculty of Fisheries and Marine Science, Bogor Agricultural University (IPB), Bogor, West Java-Indonesia

$$C_n = \sqrt{2S(\omega_n)\Delta\omega}$$

$$S(\omega) = \frac{172{,}8}{\omega^5}\left(\frac{H_{1/3}^2}{T_{01}^4}\right)\exp\left[-\frac{691}{\omega^4 T_{01}^4}\right] \tag{5}$$

Where H 1/3 is significant wave heights, T_{01} is mean wave period.

Because of the random process of both waves and fishing boat motions, the probalistic approach is needed to apply for evaluating the probality of capsize of fishing boat. This approach is linearized near the vanishing stability of negatif arm curve GZ as follows.

$$\ddot{\phi} + 2\alpha_e\dot{\phi} + \omega_v^2(\phi_v - \phi) = f(t) \tag{6}$$

as shown in figure 3.

Then the solution of $\phi(t)$ is

$$\phi(t) = A.e^{\lambda_1 t} + Be^{-\lambda_2 t} + \phi v \tag{7}$$

$$A = \frac{\lambda_2(\phi_0 - \phi_V) + \phi_0}{\lambda_1 + \lambda_2},$$

$$B = \frac{\lambda_2(\phi_0 - \phi_V) - \phi_0}{\lambda_1 + \lambda_2}$$

$$\lambda_1 = \sqrt{\alpha_e^2 + \omega_v^2} - \alpha_e \; \lambda_2 = \sqrt{\alpha_e^2 + \omega_v^2} + \alpha_e$$

$$\omega_e^2 = \frac{\omega}{I_x J_x}\left(\frac{\partial GZ}{\partial \phi}\right)_{\phi=\phi_V} \tag{8}$$

where F(t) is the wave excitation, ϕ_0 and ϕ_0 are the initial values at the local time in the range $\Delta\phi$.

The probability of capsizing during the time T canbe calculated is

$$P(T) = 2P(\phi > \phi_0).\ P(A > 0) \tag{9}$$

3. Result and Discussion

The first term in Fig. 7 develops the rolling into an unstable behaviour when the coefficient A>0 because λ_1 is always positive. Thus if the coefficient A>0 for positive rolling angle, the capsizing will take place and if the coefficient A<0 then the capsizing will not take place because the rolling swings back to the apposite direction. Consequently, It is pointed out that the sight of the coefficient A is a criterion of the critical rolling. The influence of wave excitation is small in the capsize process because the fishing boat loses sensitivity to wave excitation when the rolling angle is bigger than the angle at the maximum of GZ curve.

Several example of critical modes simulated by numerical computation are presented here. The principal dimention of the Padang fishing boat are in Table 1 and its body plan. The righting arm curve GZ in Fig.4. The example of time histories at roll and pitch in waves of the height near critical modes leasing to capsize use in Fig. 5 and Fig.6.

The probability of up-crossing P (ϕ > ϕ_0) and probability of coefficient A, P(A>0) can be obtained from the time histories at critical rolling. Presented in Fig. 7. Finally the maximum probability of capsizing during time T as shown in Fig.8. The probability of capsizing during the given time T is in the highest occurance at the heading angle $\lambda = 45^0$ for GM = 0.318 m and heading angle $\lambda = 60^0$ for GM = 0.6 m. Since the vanising stability angle remainbly vary with the relative position of fishing boat to wave when the fishing boat is navigating with the heading angle $\lambda = 0$. This effect is not taken into consideration for probability of capsizing computation, that may be the reason why capsizing probability is very small.

4. Conclusions

The probability of capsize in random seas are investigated by making use of mathematical model for numerical simulation of fishing boat rolling motion. The conclusion are summarized as follow :

(1). The fishing boat has a tendency to capsize in quartening seas more than in following seas. This is because the rolling of fishing boat in quartening seas is influented by both of wave induced stability and wave excitation.

(2). The capsizing event in lower encounting frequency range is more dangerous than in a higer frequency range. because the rolling motion at lower frequency is directly developed from periodic wave induced stability.

(3). The probability of capsize in a random sea is in a higer occurance when the fishing boat is navigating in quartening seas. This tendency is the same as results of free running model experiment.

(4). The effect of wave induced stability on the capsizing probality is difficult to consider because the control point ϕ_0 changes with relative position of fishing boat to waves. This will be problem to be considered in the future.

References

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Tabel 1 Dimensi Utama Kapal Ikan Bungus, Padang

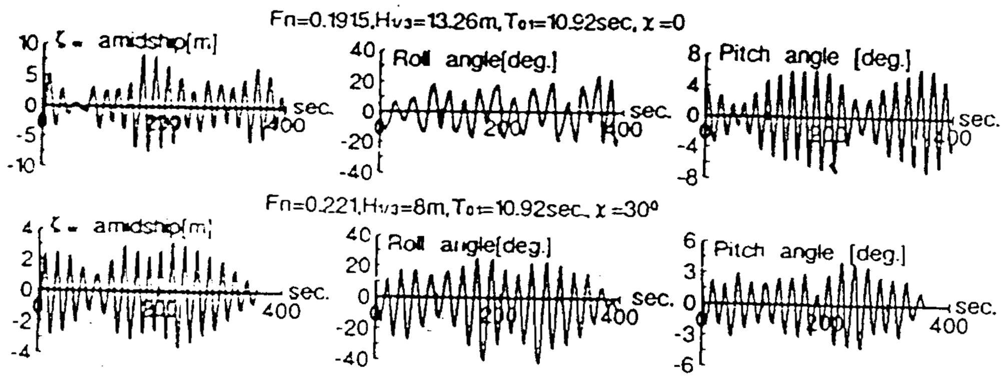
Dimensi	Unit
Panjang seluruh,LOA (m)	14,88
Panjang Lpp (m)	12,80
Panjang garis air, L_{WL} (m)	13,10
Lebar moulded, B_{mld} (m)	2,58
Lebar garis air, B_{WL} (m)	2,46
Dalam, D (m	1,12
Draft, T_{load} (m)	0,90
Koefisien blok , C_B	0,48
Koefisien prismatik, C_p	0,560
Koefisien midship, C_M	0,857
GM (m)	0,41 0,46 0,51
T_ϕ (detik)	3,490 3,290 3,130

Tabel 2. Parameter Stabilitas Kapal Ikan Bungus, Padang

KG (m)	GM (m)	T_ϕ (detik)
0.65	0,61	2,86
0.70	0,56	2,98
0.75	0,51	3,13
0.80	0,46	3,29
0.85	0,41	3,49
0.90	0,36	3,72
0.95	0,31	4,01
1.00	0,26	4,38
1.05	0,21	4,87
1.10	0,16	5,58
1.15	0,11	6,73

Periode rolling $T_\phi = \dfrac{2CB}{\sqrt{GM}}$, $C = 0{,}373 + 0{,}023\dfrac{B}{d} - 0{,}043\dfrac{L}{100}$

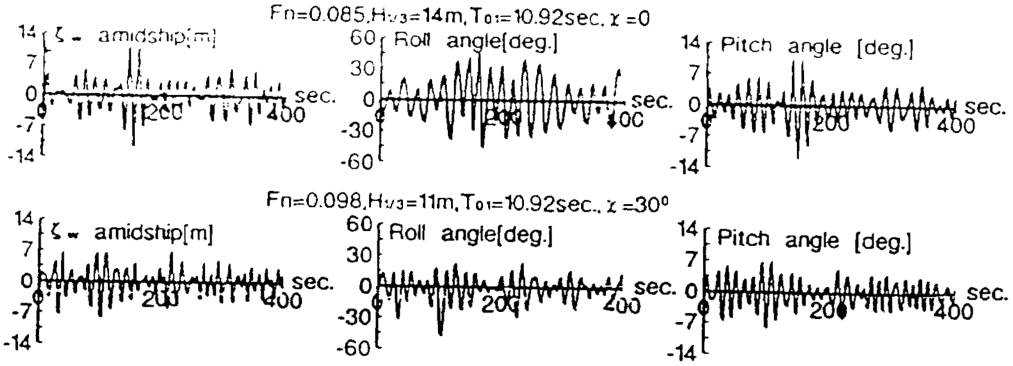
L=panjang kapal, B lebar, d draft dan GM tinggi metasenter.



$Fn=0.1915, H_{1/3}=13.26m, T_{01}=10.92sec, \chi=0$

$Fn=0.221, H_{1/3}=8m, T_{01}=10.92sec, \chi=30^{\circ}$

Fig. Time histories of wave profile, roll and pitch angle of container at critical condition of parametric resonance for GM=0.318 m



$Fn=0.085, H_{1/3}=14m, T_{01}=10.92sec, \chi=0$

$Fn=0.098, H_{1/3}=11m, T_{01}=10.92sec., \chi=30^{\circ}$

Fig. Time histories of wave profile, roll and pitch angle of container at critical condition of parametric resonance with GM=0.6 m

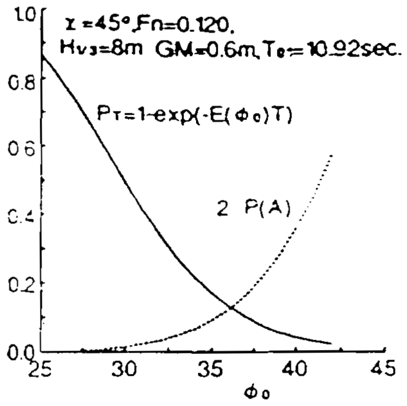


Fig. Probability of up-crossing and probability of positivity of coefficient A for various control point ϕ_0

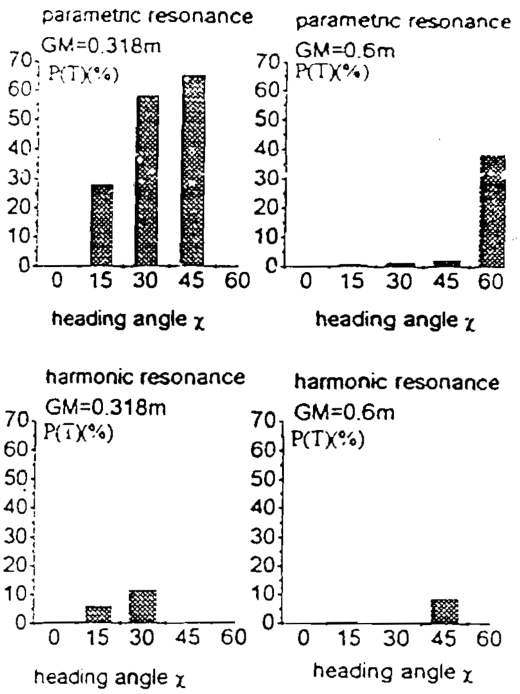


Fig. Maximum Probability of capsizing during given time T in various heading angle χ