Nippon Suisan Gakkaishi 55(11), 1921-1925 (1989)

Safety of a Peruvian Small Wooden Purse Seiner during Fishing Operations

Tadanobu Machii*[1] and Yukio Nose*[2]

(Received July 7, 1989)

The safety of a Peruvian small wooden purse seiner was examined applying the Japanese safety standard for small fishing boats. The "UNA-I" which is a prototype of a Peruvian small wooden purse seiner was used in this study.

Safety coefficient $C=\theta_p/\theta_d=1.2$ of the "UNA-I" was obtained in the worst condition of heel during fishing operation, where θ_p is the permissible maximum angle of heel and θ_d is the dynamic angle of heel. Also, for heeling caused by unexpected natural irregularities at sea, the "UNA-I" was kept in reserve $\theta_{\max}/\theta_d=3.3$, where $\theta_{\max}$ is the angle in the maximum righting moment.

The calculated static and dynamic angles of heel (θ_s, θ_d) were verified by the mesaured mean and maximum angles of experiments, and were approximately fitted with the measured values. The simplified method presented in this paper can be applied to examine the safety of similarly shaped small purse seiners utilized in Third World Countries.

Safety of a purse seiner during fishing operation is one of the most important subjects for fishermen, because it directly affects their life and property.

The safety study of a purse seiner is integarlly correlated to each one of the individual studies related to the purse winch, the purse seine and the purse seiner. Though a theoretical consideration can be found in the Semyonov-Tyan-Shansky work,[1)] any applied study is difficult to find in the world.

Since Peruvian small purse seine fishing was introduced to coastal fishery, the operation has been carried out solely by the experiences of fishermen without taking into account technical knowledge on the fishing boat stability.

Based on the results obtained by the previous study,[2)] the purpose of this paper is to examine the safety of a Peruvian small wooden purse seiner during fishing operations in order to contribute to the most important problem confronted in Peru. For an easy application, the sefety assessment was simplified as much as possible.

Materials and Methods

Fishing Boat

The fishing boat "UNA-I" which is a training and research boat belonging to the Universidad Nacional Agraria, La Molina, Peru was utilized. It has the principal dimensions of 13 gross tonnage and 36 feet length overall. This can be considered as a prototype of Peruvian small wooden purse seiners.

Fishing Gear

Fishing gear of the "UNA-I" is a rectangular purse seine made of 210 denier/15 multifilament nylon, English knotted and having a mesh size of 1 1/2″ (inch). The principal dimensions are 123 fathoms float line length, 13.3 fathoms net height and 237 kgw total weight in water.

Factors Used

The factors used in this study were as follows; the angle of heel (θ; rad), the angle of inclination made by purse line (α: rad), the angle (β; rad) between the top of the purse block and a horizontal axis passing through the center of gravity (G), the hauling tension of the winch (F; kgw), the displacement (W; kgw), the distance from G to the top of the purse block (l; m), the transverse righting lever (GZ; m), and the metacentric height (GM; m).

Table 1 shows the known values given as the specific factors of the "UNA-I". The values F and α are given from the results of experiments.

*1 Department of Marine Science and Technology, Tokyo University of Fisheries, Konan, Minato, Tokyo 108, Japan (町井紀之：東京水産大学海洋生産学科).

*2 University Museum, The Tokyo University, Hongo, Bunkyo, Tokyo 113, Japan (能勢幸雄：東京大学総合研究資料館).

Table 1. Specific values of the "UNA-I"

Displacement	W	16,669 kgw
Metacentric height	GM	0.52 m
Angle between the top of purse block and horizontal axis passing through the center of gravity (G)	β	24.3°
Distance from the G to the top of purse block	l	2.20 m
Angle of heel at the maximum righting moment	θ_{max}	32°

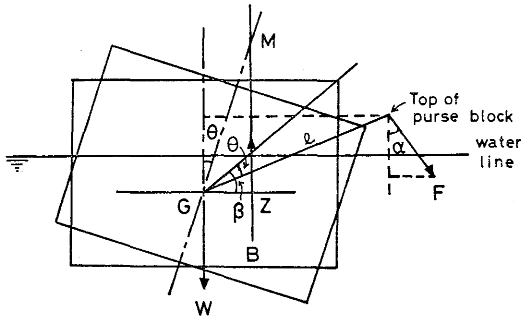

Fig. 1. Heeling when a constant hauling tension (F) acted on the boat.

G; center of gravity, B; center of boyancy, GZ; transverse righting lever, GM; metacentric height, θ; angle of heel, α; angle of inclination made by the purse line, β; angle between the top of the purese block and an horizontal axis passing through G, W; displacement, F; hauling tension of the winch, and l; distance from G to the top of the purse block.

Unknown value is θ.

Static Angle of Heel

If the boat is deviated from the upright position by increasing the angle of heel by a small quantity θ (Fig. 1), the equilibrium between heeling moment and statical stability can be expressed as

$$(F\cos\alpha)\{l\cos(\beta-\theta)\}=(W+F\cos\alpha)GZ \quad (1)$$

where since θ is very small, $\cos\theta \fallingdotseq 1$ and $\sin\theta \fallingdotseq \theta$. Also $GZ=GM\sin\theta \fallingdotseq GM\cdot\theta$. Eq. (1) can be simplified as

$$F\cdot l\cos\alpha(\cos\beta+\sin\beta\cdot\theta) =(W+F\cos\alpha)GM\cdot\theta \quad (2)$$

If F is given, put $\theta=\theta_s$, where θ_s (rad) is the static angles of heel. Then θ_s can be derived from Eq. (2) as

$$\theta_s=(F\cdot l\cos\alpha\cos\beta)/\{(W+F\cos\alpha)GM -F\cdot l\cos\alpha\sin\beta\} \quad (3)$$

Dynamic Angle of Heel

Based on Eq. (2) the equilibrium between the work done by heeling moment and dynamical stability can be expressed by

$$F\cdot l\cos\alpha\left(\cos\beta\int d\theta+\sin\beta\int\theta\, d\theta\right) =(W+F\cos\alpha)GM\int\theta\, d\theta \quad (4)$$

If F is given, put $\theta=\theta_d$, where θ_d (rad) is the dynamic angle of heel. Then θ_d can be derived from Eq. (4) as

$$\theta_d=(2\,F\cdot l\cos\alpha\cos\beta)/\{(W+F\cos\alpha)GM -F\cdot l\cos\alpha\sin\beta\} \quad (5)$$

In Fig. 1, B is the center of buoyancy.

Heeling Behavior

Fig. 2 shows a general diagram of the statical stability and arbitrarily prescribed external heeling moments caused by hauling tension (lower line I-J) and by squall (upper line M-N).

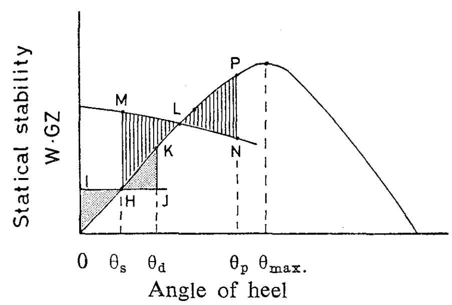

Fig. 2. General diagram of the statical stability acted external heeling moments.

Lower line I-J; constant heeling moment caused by hauling tension (F) and upper line M-N; external heeling moment caused by squall.

θ_s; static angle of heel, θ_d; dynamic angle of heel, θ_p; permissible maximum angle of heel, and θ_{max}; angle in the maximum righting moment.

The value θ_p is taken one of the smaller of the two values $\theta_p=12°$ or $\theta_p=\tan^{-1}(2F_{bd}/B)$. F_{bd}; freeboard and B; breadth.

Heeling caused by a Hauling Tension at the Upright Position

Suppose that the boat floats initially at the upright position 0. Let the boat in this position be inclined only by a constant hauling tension (F).

The boat is inclined to the position K corresponded to the dynamic angle of heel (θ_d). After that the boat returns to the position H corresponded to the static angle of heel (θ_s). This movement occurs in order to hold the equality of the work done by the heeling moment (shaded area 0HI) and the work done by the righting moment (shaded area HJK), because at the position K the righting moment is greater than the heeling moment.

Heeling caused by a Squall at the Inclined Position

Suppose that the boat is in equilibrium at position H. Let the boat in position H be struck by a squall on the opposite side of the fishing operation. Then the boat is inclined to the position P. This inclination occurs in order to hold the equuality of the work done by the heeling moment (shaded area HLM) and the work done by the righting moment (shaded area LNP). Finally the boat returns to the position L and stays in equilibrium in this position.

Results and Discussion

Definition of the Safety Coefficient

In this study the safety coefficient (C) is defined as

$$C=\theta_p/\theta_d \quad (\geqq 1) \tag{6}$$

The Japanese safety standard for small fishing boats[3] suggests the permissible maximum angle of heel (θ_p; rad) caused by fishing operation as

$$\theta_p \leqq 12° \quad (=0.2094 \text{ rad})$$

or

$$\theta_p \leqq \tan^{-1}(2\,F_{bd}/B) \tag{7}$$

where F_{bd} (m) is the freeboard and B (m) is the breadth. The value θ_p must be taken as the smaller of the two values as shown above.

Comparing Eq. (3) and Eq. (5), the following relationships can be obtained

$$\theta_d=2\theta_s \tag{8}$$

Determination of the Safety Coefficient

The F in Eq. (3) can be rewritten by

$$F=(1/\cos\alpha)\,[W\cdot GM\cdot\theta_s/\{l\cos\beta + (l\sin\beta-GM)\theta_s\}] \tag{9}$$

In Eq. (9), since θ_s is very small as mentioned already, $l\cos\beta \gg (l\sin\beta-GM)\theta_s$. Consequently, the static angle of heel due to F can be simplified as

$$\theta_s=\{(l\cos\beta)/(W\cdot GM)\}F\cos\alpha \tag{10}$$

According to the results obtained in the experiment, the hauling tension (F) in standard fishing operation was

$$F=367 \text{ kgw}$$

Likewise, the angle of inclination made by purse line (α) was, in the pursing stage ($0<t\leqq 171$ s)

$$\alpha=40.2° \quad (=0.7016 \text{ rad})$$

and in the hauling stage ($171<t\leqq 238$ s)

$$\alpha=0° \quad (=0 \text{ rad})$$

where t is the time lapse of fishing operation.

Using the known values of the specific factors (Table 1) and the values of the constants mentioned above (F and α), the values of the safety coefficient (C) can be calculated in two stages. Table 2 shows the result obtained.

The value C must be determined at the worst condition of heel, *i.e.*, in this study $\theta_p=12°$ ($<16.9°$) under the hauling stage for the dynamic angle of heel. Therefore, the safety coefficient of the "UNA-I" in the worst condition is determined as $C=1.2$ (Table 2).

Since the angle in the maximum righting moment (θ_{max}) of the "UNA-I" was given as $\theta_{max}=32°$ (Table 1) by the previous study,[2] the value $\theta_{max}/\theta_d=3.3$ is kept in reserve for the external

Table 2. Results obtained of the values of the safety coefficient (C)

		Pursing stage		Hauling stage	
Static angle of heel	θ_s (°)	3.7		4.9	
Dynamic angle of heel	θ_d (°)	7.4		9.8	
Permissible maximum angle of heel	θ_p (°)	12.0	16.9*	12.0	16.9*
Safety coefficient	C	1.6	2.3	1.2	1.7

* the value calculated by $\theta_p=\tan^{-1}(2F_{bd}/B)$ applied freeboard $F_{bd}=0.55$ m and breadth $B=3.61$m.

heeling moment caused by unexpected natural irregularities at sea such as squalls, winds, waves, swells etc.

Relation between the Safety Coefficient and the Hauling Tension

From Eqs. (7), (8) and (10), F is written as

$$F=(W\cdot GM\cdot\theta_p/l\cos\beta)\{1/(2C\cos\alpha)\} \qquad (11)$$

Based on Eq. (11), the value F can be calculated numerically for the range $1\leqq C\leqq 2$ in two stages. Fig. 3 shows the results obtained. From the figure, it is clear that if a high safety coefficient is desirable, the hauling tension must be reduced.

The lower curve "A" in Fig. 3 which is the worst condition of heel should be used in selecting the safety coefficient taking an appropriate value for an aimed fishing ground.

Verification of the Calculated Angles of Heel

Experiments on the angle of heel during fishing operation of the "UNA-I" were done 4 times at sea. Fig. 4 shows the result obtained. In the figure, the mean angles of heel measured by experiments were approximately fitted with the calculated values of the static angle of heel (θ_s).

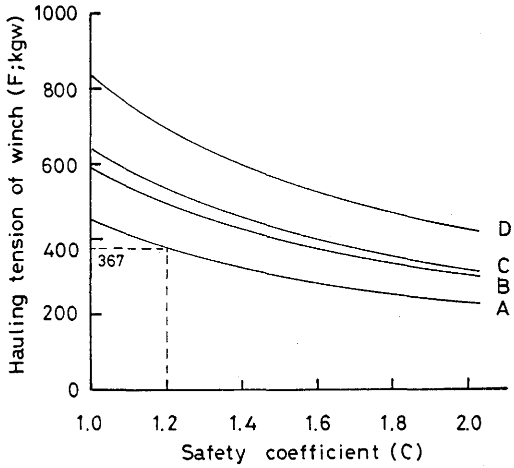

Fig. 3. Relationships between the safety coefficient (C) and the hauling tension (F) in the "UNA-I" under different conditions.

A; $\theta_p=12.0°$ at hauling stage, B; $\theta_p=12°$ at pursing stage, C; $\theta_p=16.9°$ at hauling stage, and D; $\theta_p=16.9°$ at pursing stage.

From "the Japanese safety standard for small fishing boats",[5] the value $\theta_p=12.0°$ and $\theta_p=16.9°$ are obtained. The later is calculated by $\theta_p\leqq\tan^{-1}(2F_{bd}/B)$ applying $F_{bd}=0.55$ m and $B=3.61$ m in the previous study.[2]

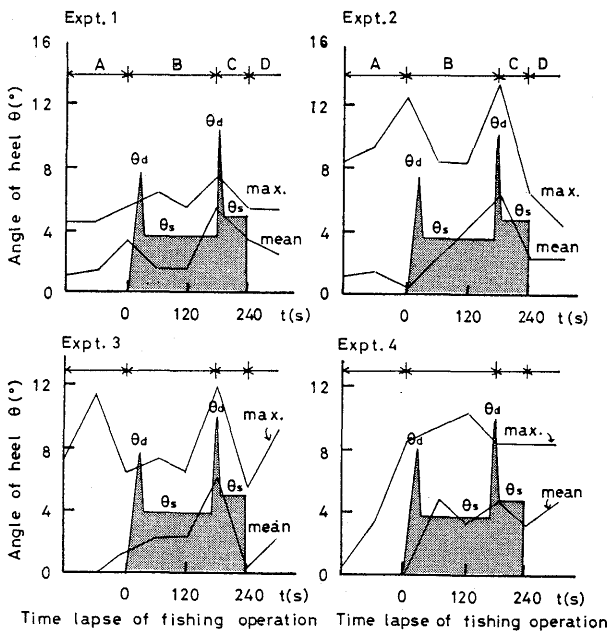

Fig. 4. Comparison between calculated angles of heel (θ_s and θ_d) and measured angles of experiments (mean and max.) during the time lapse of fishing operation of the "UNA-I".

θ_s; static angle of heel and θ_d; dynamic angle of heel, suffix "1"; pursing stage and suffix "2"; hauling stage.

A; pre-arrangement, B; pursing stage; C; hauling stage, and D; post-arrangement. Shaded area shows the calculated inclination range θ_s and θ_d.

On the other hand, the maximum angles of heel measured by experiments were mostly affected by unexpected natural irregularities mentioned already. Except experiment No. 1 in Fig. 4, the calculated values θ_s and θ_d are included within the range of the measured mean and maximum values.

The authors examined, as the first step, the safety of a Peruvian small wooden purse seiner applying directly the Japanese permissible maximum angle of heel. In this case, the safety coefficient C must be expressed by the dynamic angle of heel (θ_d).

The angle at the maximum righting moment ($\theta_{\max}$) of Peruvian purse seiners ought to be slightly different from that of the Japanese one-boat purse seiners. Consequently, as a future subject, the Peruvian permissible maximum angle of heel (θ_p) has to be determined independently by studying unknown local natural factors such as meteorological and oceanographical conditions of the Peruvian coast.

Since the "UNA-I" is considered as a prototype of Peruvian small wooden purse seiners, under different conditions of the specific factors for each individual boat, the simplified method presented in this study is effective and useful to examine the safety of similar-shaped small purse seiners utilized in the Third World Countries.

Acknowledgments

The authors wish to thank Professor Víctor Paredes G., and Associate Professor and Captain of the "UNA-I" Luis Garayar M., Universidad Nacional Agraria, La Molina, Lima, Peru, for their sincere collaborations, and all the members of Departamento de Extracción Pesquera of the same University for their help to realize experiments at sea.

References

1) V. Semyonov-Tyan-Shansky: in "Statics and Dynamics of the Ship", Peace Publishers, Moscow, 1969, pp. 201–213.
2) T. Machii and O. Malpica: *J. Tokyo Univ. Fish.*, **57**, 295–309 (1989).
3) Japanese Fishery Agency: in "Kogata Gyosen Anzen Kijun", Tokyo, 1972, pp. 49 (in Japanese).

Nippon Suisan Gakkaishi : Formerly *Bull. Japan. Soc. Sci. Fish.*