Consideration of Risk Level in Terms of Damage Stability of Old Ship

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Abstract: The risk analysis of passenger ships in terms of damage stability was conducted. Through this analysis, the relation between risk level and applied regulation was examined to clarify the effect of regulation for ensuring the safety. Consequently, it is clarified that risk level of SOLAS90 is generally low. It is also clarified that amendments of regulation improve the safety.

Key words: Damage stability, passenger ship, risk analysis, SOLAS90 and SOLAS2009, casualty database.

1. Introduction

The International Maritime Organization (IMO) is examining passenger ship safety. In this task, it is considered that safety level of passenger ships should be assessed for the further consideration.

Based on this background, the risk analysis of passenger ships, these are Cruise ships and RoPax vessels, in terms of damage stability was conducted utilizing IHS Fairplay Casualty and Ship databases (IHSF database) to contribute the technical background for the assessment.

Casualty data of collision, contact, wrecked, stranded and foundered accidents were focused in this analysis because these casualties have strong relation with the damage stability.

Through this analysis, the relation between risk level and applied regulation was examined to clarify the effect of regulation for ensuring the safety. In this study, data was separated into two kinds of ships. One is the ships built before application of SOLAS90. Another is the ships built in or after application of SOLAS90. The safety level of old ships, which was defined as the ships built before application of SOLAS90, was clarified based on this risk analysis. Currently, SOLAS2009 has been developed in the IMO. However, there are few casualty data, which makes it difficult to conduct a meaningful risk analysis. Furthermore, it is considered that safety level ensured by the SOLAS2009 is the same as that ensured by the SOLAS90.

Therefore, in this study, SOLAS90 was treated as an index for the examination of the effect of regulation on the safety revel in terms of damage stability.

Consequently, it is clarified that F-N curves for cruise ship of SOLAS 90 and pre-SOLAS 90 locate within ALARP (As Low As Reasonably Practicable) region. However, in the case of SOLAS90, it is found that only one serious accident raised the risk level and the risk level except this accident is quite low. It is also clarified that F-N curves for RoPax vessel of SOLAS 90 locates within NEGLIGIBLE region.

Based on the comparison of risk level, it is concluded that safety was relatively enhanced due to the revision of regulation. It is clarified that risk level of ships before implementation of SOLAS90 was not necessarily low.

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2. Risk Analysis in terms of damage stability

2.1 Scope of this study

In this study, Risk analysis (step 2 of FSA[1]) was carried out based on IHSF database in order to consider the risk level in terms of damage stability of old ships. The subject ships of this risk analysis were following two types of passenger ships. One was the type which complied with SOLAS 90, and the other was the type which did not.

2.2 Used data

Based on the casualty and ship databases of IHSF, the risk analysis of Cruise ships and RoPax vessels 1,000GT or above was conducted.

2.3 Ships

This study focused on Cruise ships and RoPax vessels so that the following codes were collected in "STATCODE" of IHSF, for example A36 (RoPax) and A37 (Cruise/Passenger).

A36A2PR: Passenger/Ro-Ro Ship (Vehicles)
A36A2PT: Passenger/Ro-Ro Ship (Vehicles/Rail)
A36B2PL: Passenger/Landing Craft
A37A2PC: Passenger/Cruise
A37B2PS: Passenger Ship

2.4 SOLAS 90 ships

In this study, to clarify the relation between compliance of regulation and safety level, ships are categorized in accordance with following definition;

- ✓ Pre-SOLAS 90 ships: the ships built in or before 1989,
- ✓ SOLAS 90 ships: the ships built in or after 1990.

2.5 Casualties

The data of some categories of collision, contact, grounding and foundered were extracted for analysis in this study because they have strong relation with stability issue.

In the IHSF, they are categorized as the codes of CN (collision), CT (contact), WS (grounding), and FD (foundered). Table 1 shows the definitions of these 4 categorized casualties. In addition to those casualties, for the comparison, other 5 major casualties are shown in table 1.

Data from 1978 to 2012 are extracted as pre-SOLAS 90 ships. Data from 1990 to 2012 are extracted as SOLAS 90 ships.

Table 1 Casualty codes and their definitions (in IHSF)

Casualty (Category)	Casualty Code	Definition
Foundered(1)	FD	Includes ships which sank as a result of heavy weather, springing of leaks, breaking it two etc., and not as a consequence of categories 2-7 or 9.
Wrecked /Stranded (2)	WS	Includes ships reported hard and fast for an appreciable period of time and cases reported touching sea bottom. This category includes entanglement on under water wrecks.
Contact (3)	CT	Striking or being struck by an external substance but not another ship or the sea bottom (see categories 2/4). This category includes striking drilling rigs/platforms, regardless of whether in fixed position or in tow.
Collision (4)	CN	Striking or being struck by another ship, regardless of whether under way, anchored or moored. This category does not include striking under water wrecks.
Fire & Explosion (5)	FX	Where the fire and/or explosion is the first event reported (except where first event is a hull/machinery failure

		leading to fire/explosion). Note: It therefore follows that casualties involving fires and/or explosions after collisions, stranding etc., are categorized under 'Collision', 'Stranding'. Scavenge fires and crankcase explosions are included in this category.
Missing Vessel (6)	MG	After a reasonable period of time, no news having been received of a ship and its fate being therefore undetermined, the ship is posted as "Missing" at the Corporation of Lloyd's and is included in the Missing category on the data base together with similar cases reported by other reliable sources. Note: In peacetime, missing ships are considered as losses by marine perils.
War Loss /Damage During Hostilities (7)	LT	This category is intended to encompass damage or other incidents occasioned to ships by hostile acts.
Hull/ Machinery Damage (8)	HM	Includes ships lost or damaged as a result of hull/machinery damage or failure which is not attributable to categories 1-7 or category 9.
Miscellaneous (9)	XX	Includes ships which have been lost or damaged which, for want of sufficient information, or for other reasons, cannot be classified.

2.6 Review of the casualty data

The fatal accident data for foundered after damage and flooded is available for analysis in consideration of stability issue. However, the data for the accident of fire on the deck after damage is not available for the analysis of stability issue. Therefore, all fatal accident data one by one in the categories of CN (collision), CT (contact), WS (Wrecked/Stranded) and FD (foundered) were intensively checked. As a result, insufficient or inadequate data were removed. The detail of information of the removed data is shown in Table 2 and Table 3.

(1) Cruise ships

A casualty data shown in Table 2 was removed from 10 fatal accidents data of Cruise ships 1,000 GT or above both pre-SOLAS 90 and SOLAS 90 ships, which were categorized as CN, CT, WS and FD in IHSF data (1978-2012). This ship is among SOLAS 90 ship.

(2) RoPax

4 casualties (CN: 3 and FD: 1) shown in Table 3 were removed from the 33 fatal accidents data of RoPax vessels 1,000 GT or above. The accident in the first row of Table 3 was that of pre-SOLAS 90 ships. Other 3 accidents were those of SOLAS 90 ships.

Table 2 Detail of removed data from IHSF Casualty Database (1978-2012) (Cruise 1,000GT or above)

Casualty Code	No. of fatalities	Reason for removal
CN	4	This casualty is not related to the stability issue, because the crews on the deck were dead by the impact of collision [2].

Table 3 Detail of removed data from IHSF Casualty Database (1978-2012) (RoPax 1,000GT or above)

Casualty Code	No. of fatalities	Reason for removal
CN	18	This casualty is not related to the stability issue because of fire after collision [3].
FD	970	This ship was a government-owned and domestic vessel.
CN	1	This casualty is not the RoPax ships but the fishing vessel [4].
CN	1	This accident is excluded because of

duplication [5].

3. Methods of Calculating Risk

In this study, PLL (Potential Loss of Life) and F-N diagram were considered as risk. Calculating methods for them are shown in below.

3.1 PLL (Potential Loss of Life)

PLL [fatalities/(ship*year)] is given by eq.(1) where N is the total number of annual fleet of the subject ship in considered period, k is the total number of fatalities in considered period.

$$PLL = \frac{k}{N} \tag{1}$$

3.2 F-N diagram

F-N diagram is a continuous graph with the ordinate representing the cumulative frequency distribution of j or more fatalities and the abscissa representing the consequence (j fatalities)[1]. A value of a vertical axis in F-N diagram is obtained by eq. (2) where n_k is the number of casualties with exactly k fatalities, k_{max} is the maximum number of fatalities. F (j) shows frequency of accidents in which persons of j and above are killed.

$$F(j) = \sum_{k=j}^{k_{max}} \frac{n_k}{N} \tag{2}$$

4. Results of Calculating Risk of Cruise ships

4.1 Fleet

Fig.1 shows the results of calculation of fleet of Cruise ships and Table 4 provides the total number of annual fleet. It is found that the fleet of pre-SOLAS 90 ships decreases gradually from 1990, on the other hand, that of SOLAS 90 ships is increasing every year. The fleet of SOLAS 90 ships is larger than that of pre-SOLAS 90 ships from 2007.

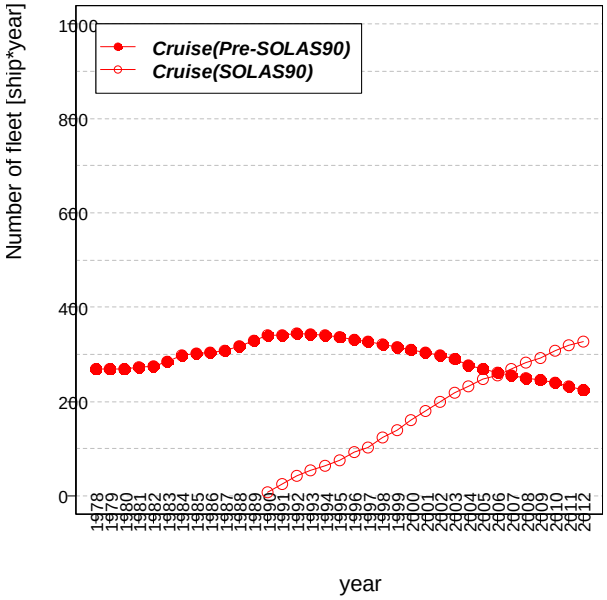

Fig.1 Chronological changes of fleet of Cruise ships (1,000GT or above)

Table 4 Total number of annual fleet of Cruise ships (1,000GT or above)

	Total number of fleet [ship*year]
Pre-SOLAS 90	10,291
SOLAS 90	4,019

4.2 PLL (Potential Loss of Life)

PLL of cruise ships of the above-mentioned 4 types of casualties are shown in Table 5 and Fig.2.

The following findings are derived:

- PLL of SOLAS 90 ships are lower than that of pre-SOLAS 90 ships except in the case of WS (Wrecked/Stranded).
- PLL of SOLAS 90 ships indicates zero except WS. The reason is that no accident with loss of life has happened except WS. On the other hand,

only the accident of Costa Concordia in January 2012 affects the PLL of WS.

- PLL of WS is the highest and that of CT (Contact) is the lowest in pre-SOLAS 90 ships.

Table 5 Number of fatalities and PLL of Cruise ships (1,000GT or above)

	Pre-SOLAS 90		SOLAS 90	
	No. of fatalities	PLL	No. of fatalities	PLL
CN	13	1.26×10^{-3}	0	0.00
CT	3	2.92×10^{-4}	0	0.00
WS	61	5.93×10^{-3}	32	7.96×10^{-3}
FD	15	1.46×10^{-3}	0	0.00

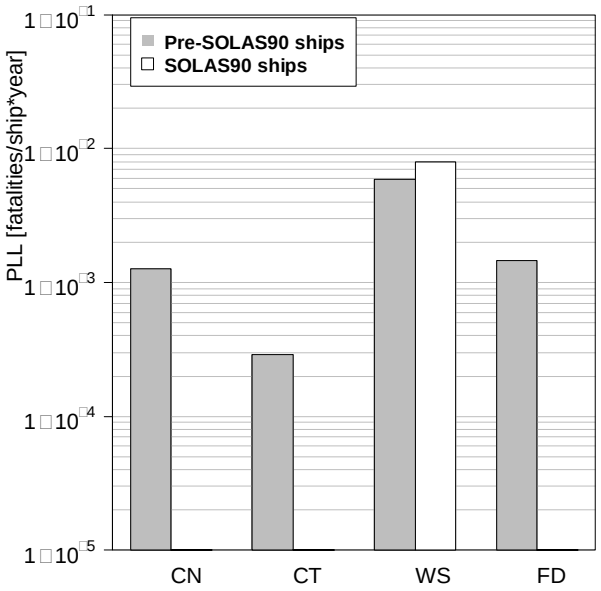

Fig.2 PLL of Cruise ships (>=1,000GT)

4.3 F-N diagram

F-N diagrams of cruise ships of the above-mentioned 4 types of casualties are shown in Fig.3. The ALARP limits[6] are also shown in Fig.3.

Following findings are clarified:

- Both F-N curves of SOLAS 90 and pre-SOLAS 90 locate within ALARP region.
- Maximum number of 58 fatalities of pre-SOLAS 90 ships is larger than that of SOLAS 90 ships.

  This accident of pre-SOLAS 90 ships is a grounding casualty.

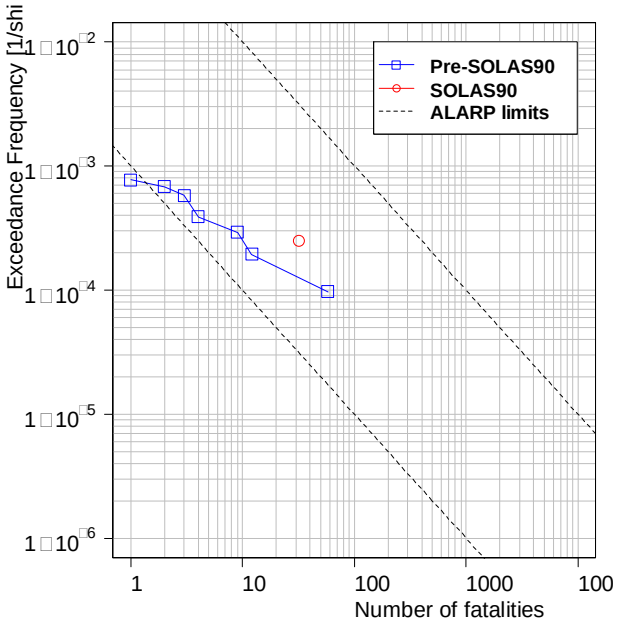

Fig.3 F-N curves of Cruise ships (1,000GT or above)

5. Results of Calculating Risk of RoPax vessels

5.1 Fleet

Fig. 4 shows the results of calculation of fleet of RoPax vessels under the above data and Table 6 provides the total number of annual fleet. It is found that the fleet of pre-SOLAS 90 ships decreases gradually from 1990. It is also found that the fleet of SOLAS 90 ships is increasing every year. The fleet of SOLAS 90 ships is larger than that of pre-SOLAS 90 ships from 2011.

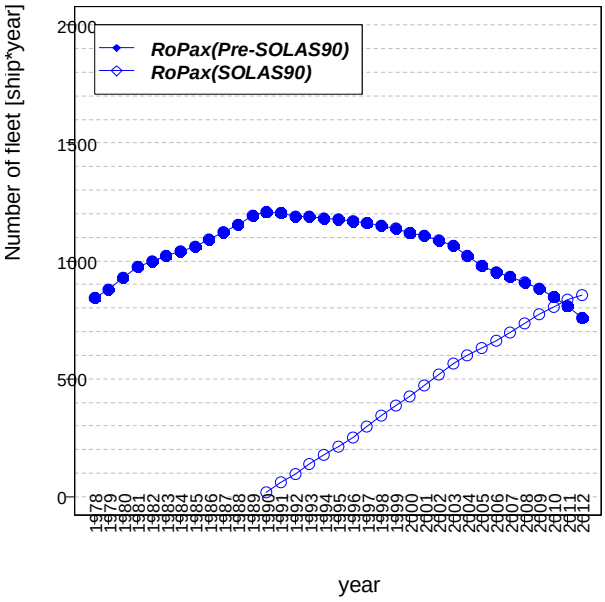

Fig.4 Chronological changes of fleet of RoPax vessels (1,000GT or above)

Table 6 Total number of annual fleet of RoPax vessels (1,000GT or above)

	Total number of fleet [ship*year]
Pre-SOLAS 90	36,543
SOLAS 90	10,554

5.2 PLL (Potential Loss of Life)

PLL of RoPax vessels of the above-mentioned 4 types of casualties are shown in Table 7 and Fig.5.

We can get a sense of the following from Table 7 and Fig.5:

- PLL of SOLAS 90 ships indicates zero except CT (Contact) because no accident with loss of life has happened except CT.
- PLL of FD (Foundered) is the highest and that of CT is the lowest in pre-SOLAS 90 ships.
- PLL of CT of SOLAS 90 ships is higher than that of pre-SOLAS 90 ships due to the difference of number of fleet. It is clarified that there is one fatality in each ship. Therefore, the difference of number of fleet induces the difference of PLL.

Table 7 Number of fatalities and PLL of RoPax vessels (1,000GT or above)

	Pre-SOLAS 90		SOLAS 90	
	No. of fatalities	PLL	No. of fatalities	PLL
CN	175	4.79×10^{-3}	0	0.00
CT	1	2.74×10^{-5}	1	9.48×10^{-5}
WS	1,381	3.78×10^{-2}	0	0.00
FD	1,692	4.63×10^{-2}	0	0.00

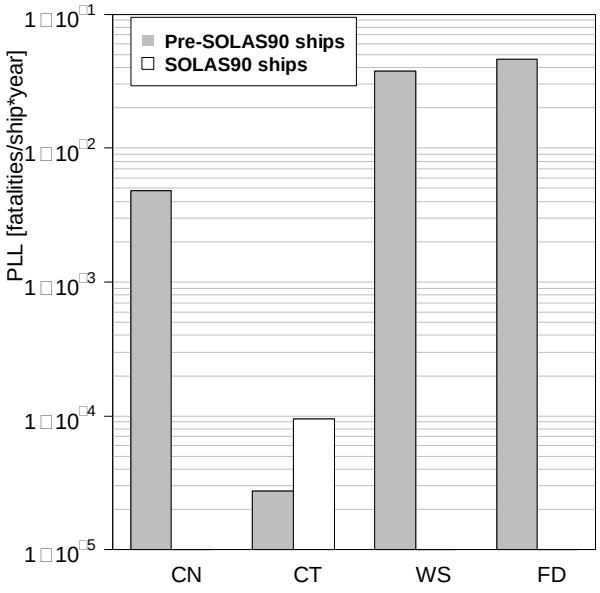

Fig.5 PLL of RoPax vessels (1,000GT or above)

5.3 F-N diagram

F-N diagrams of RoPax vessels of the above-mentioned 4 types of casualties are shown in Fig.6. The ALARP limits[6] are also shown in Fig.6.

Following findings are clarified:

- F-N curve of pre-SOLAS 90 ships locates within ALARP region.
- F-N curve of SOLAS 90 ships locates within NEGLIGIBLE region.
- Maximum number of fatalities of pre-SOLAS 90 ships is quite larger than that of SOLAS 90 ships.

This accident with maximum fatalities of pre-SOLAS 90 ships is a foundered casualty. This casualty is the accident of ESTONIA in September 1994. It is recorded that the total number of fatalities and missing is reported as 852 in IHSF.

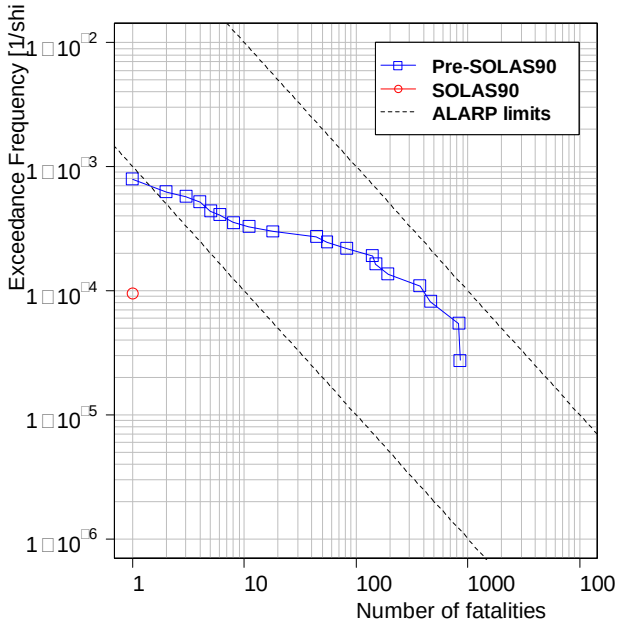

Fig.6 F-N curves of RoPax vessels (1,000GT or above)

6. Conclusions

Based on IHS Fairplay World Casualty Statistics database (hereinafter "IHSF"), risk level in terms of damage stability is investigated. Consequently, the following findings are clarified:

1) Regarding the accidents of collision, contact, grounding and foundered of Cruise ships, PLL of SOLAS 90 ships is lower than that of pre-SOLAS 90 ships except in the case of WS (Wrecked/Stranded). The reason is that no accident with loss of life has happened except WS. On the other hand, only the accident of Costa Concordia affects the PLL of WS.

2) In terms of the Cruise ships, both F-N curves of SOLAS 90 and pre-SOLAS 90 locate within ALARP region.

3) Regarding the accidents of collision, contact, grounding and foundered of RoPax vessels, PLL of CT of SOLAS 90 ships is higher than that of pre-SOLAS 90 ships due to the difference of number of fleet. It is clarified that there is one fatality in each ship. Therefore, the difference of number of fleet induces the difference of PLL.

4) In terms of the RoPAX vessel, F-N curve of pre-SOLAS 90 ships locates within ALARP region. On the other hand, F-N curve of SOLAS 90 ships locates within NEGLIGIBLE region. Particularly, Maximum number of fatalities of pre-SOLAS 90 ships is quite larger than that of SOLAS 90 ships due to the accident of ESTONIA, which is a pre-SOLAS 90 ship.

5) Consequently, it is concluded that safety is relatively enhanced due to the revision of regulation. It is clarified that risk level of ships before implementation of SOLAS90 is not necessarily low.

On the other hand, it is considered that not only damage stability aspects but also operational aspects should be considered for comprehensive measure of safety because serious accident, which raise the risk level, occurs due to the some kinds of accidental causes.

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