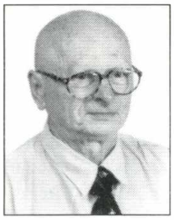

LECH KOBYLIŃSKI, Prof.,D.Sc.,N.A.
Technical University of Gdańsk,
Polish Academy of Sciences

Operational aspects of safety from the stability point of view

SUMMARY

Design stability standards were ultimately adopted by IMO quite recently. The designers and operators of ships are, however, aware that the standards do not constitute an ultimate solution. At present much attention is devoted to the operational aspects of stability because it is well known that 70 to 80 % of casualties are caused by human unreliability. The author considers operational aspects of stability including human factor and discusses several methods necessary to deal with the situation in order to safeguard safe ship operation in various weather conditions.

The paper presented at the conference EXPLO-SHIP '99 held on 10 to 12 May, 1999, in Międzyzdroje.

INTRODUCTION

For last 25 years more and more attention has been paid to safety at sea and marine environment protection. There is a common opinion that shipping is not sufficiently safe although the number of sea casaulties systematically lowers and the statstical data indicate that it is not a specially hazardous activity in comparison with other fields of human activities, first of all with road transport. The serious accidents occuring from time to time such as that of the tanker AMOCO CADIZ which caused destruction of marine environment along the coast of Brittany, and the disasters of such ferries as : HERALD OF FREE ENTERPRISE, HEWELIUSZ and ESTONIA contribute to that opinion.

Today the probability of loss of life at sea is lower than that in land transport, but still 15 to 20 ships per year, of the total tonnage of 100 000 RT, meet with a stability accident. The most dangerous accidents at sea are those when the ship is totally lost and, in consequence, usually connected with huge loss of lives. Cause analysis of such accidents shows that about 60% of them are collisions (of two ships or between a ship and permanent object), 20% - fire and explosions, and about 19% - stability accidents. The latter events, being not the most frequent, cause however the highest loss of lives. In many cases capsizing of a ship results from collision or fire.

During the last quarter of this century a lot of effort have been put into elaboration of stability standards for the intact ships. This has brought fruits a.o. in the form of the international standards for stability of different ships, adopted by International Maritime Organization (IMO). These are designing standards, i.e. the provisions which new-designed ships have to comply with. Undoubtedly the standards contributed to increasing the ship safety against capsizing. During that period much less attention has been paid, however, to safety-related operational aspects of ship stability, which play a decisive role in most accidents as it can be seen from their analyses.

Therefore in this paper the author considers the operational aspects with human factor also taken into account.

BASIC PHILOSOPHY OF STABILITY STANDARDS

The fact of complying with the stability standards by a ship does not automatically mean that the ship is safe in respect of stability. Stability accident analysis reveals that the ships which do satisfy stability standards sometimes capsize whereas the ships not fulfilling those standards operate safely. One has only to refer to the analysis performed by IMO [1]. It becomes obvious if one takes into account that the standards are elaborated on the basis of the statistical discrimination analysis - the fact often not understood by the lawyers who regard the fact of not complying with the stability standards by a ship as the cause of the ship's accident. Hence the accident statistics based on the verdicts of the Maritime Chambers is rather of no use from the point of view of the stability theory [2].

However many engineers and lawyers emphasize that designing the ship to be „foolproof" as regards stability would be an unrealistic task [3], and that the problem of establishing the stability standards is too complicated to be solved once and for all. Not going into details it can be stated that the present stability standards are based on not very perfect statistics and on the considerations to which many simplified assumptions were applied. Authors of the standards, from the very beginning of their implementation, have been aware that their application does not provide perfect safety and that operation is of a great importance. For this reason the distinct warning related to the matter was introduced into the preamble of IMO Resolution A.167 (ES.IV). In its text attention is paid to the fact that the ship master, apart from complying with the standards, should act with deliberation and adhere to good seamanship.

The above mentioned statement indicates that the operational aspect was considered an important element of ship safety with respect to stability. Nevertheless in the present stability standards not many requirements are of operational character. It is clear that safe ship operation depends on human abilities and possibilities therefore the so called „human factor" plays the basic role.

SYSTEM APPROACH TO SAFETY AND IMPORTANCE OF OPERATIONAL FACTOR

To assure safety against capsizing of the ship at sea it is not enough to aim at improving the design standards. Stability-related safety should be considered as a system. This opinion was expressed by this author many years ago [4], and other scientists represented similar opinion too [5]. The system approach was used by IMO to elaborate the Code of Stability for Ships of All Types - Res. IMO A.749(18).

The stability-related safety system should cover at least four elements : ship, cargo, environment, exploitation (operation) [5]. The four elements are tightly connected to each other which can be illustrated by means of Venn's diagram (Fig.1) :

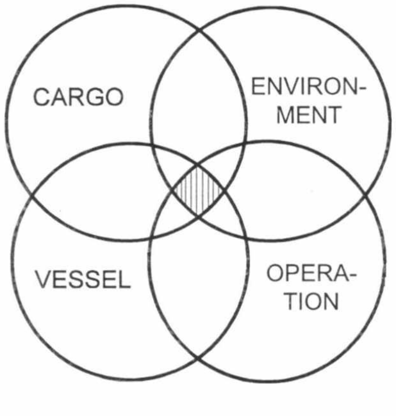

Fig.1. Four-element system of stability-related ship safety

To operate the ship means here to control her stability by crew during voyage and to safely navigate the ship. The exploitation is tightly connected with the human factor. The way in which a ship is operated influences her stability which also depends on environmental conditions and cargo distribution. Kastner [5] described the operational stability in the following way : „The operational stability determines a real situation of the ship in respect to her stability during voyage, changeable with time due to changes of cargo and ballast loads and variable sea state". The role of ship master is to control the stability and undertake appropriate actions to assure the safety.

The exploitation covering also the human factor is, according to some authors, responsible for 80% of all stability accidents [6]. Other literature sources firmly state that 80% maritime accidents are caused by human and organizational errors (HOE) [7]. A P&I Club analysis reveals that HOE is the cause of 62% accidents at sea (Fig. 2). Hence the highest attention should be paid to the operational aspects.

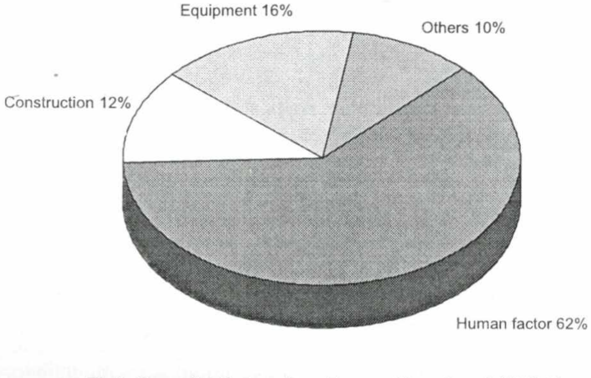

Fig.2. Cause distribution of maritime accidents (acc. P&I Club)

Importance of the operational aspects has been already recognized by the international shipping circles. IMO included the human factor problem into its activity program, and within that program the ISM Code has already been issued. Also, the necessity of implementation of the safety formal assessment in shipping was accepted by IMO which formed a special working group to deal with the problem. A way to include, at least partially, the human factor into the safety formal assessment with respect to stability was demonstrated by this author [8].

FACTORS INFLUENCING OPERATIONAL STABILITY

As it was above stated 80% sea accidents are caused by human and organization errors (HOE) ; the remaining 20% can be attributed to material and construction defects, act of God and other causes. The sea accident causes can be classified as shown in (Fig.3) [9].

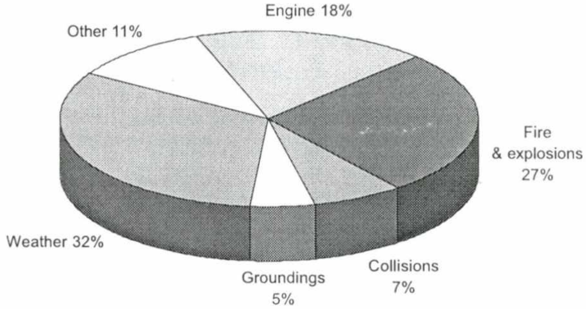

Fig.3. Classification of sea accidents by cause (acc. [9])

HOE can result from designing, building or operational errors. Design and building is responsible for about 20% HOE, the rest directly result from exploitation and depend on the following factors :

- community – culture
- organization
- human being
- system.

Community – culture

Community and its culture greatly influences the acceptable risk of human activity. In general economic factors exert pressure to limit safety demands and in consequence to increase risks as increasing the safety levels costs more. However from the exclusively economical point-of-view an optimum safety index does exist since the initial and exploitation cost increases along with increasing the safety index, but the accident cost decreases as well (Fig.4).

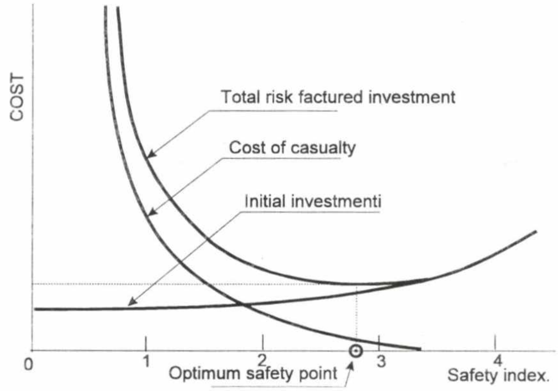

Fig.4. Optimum safety level (index) based on exclusively economical considerations

However the safety index determined from exclusively economical premises can be socially inacceptable for other reasons. Public opinion is of powerful influence. It tends to tolerate many single, minor accidents, e.g. road accidents, but it does not tolerate the single, serious accidents connected with loss of several tens or hundred lives (for instance : HEWELIUSZ or ESTONIA disaster). Particularly in result of the latter a huge, almost hysterical mass media pressure to radically increase safety requirements for the passenger ferries could be observed. It was triggered by the heavy toll of lives in result of the ferry disaster, however if only the statistical data are accounted for it can be seen that the toll is much lower than the number of lost lives due to traffic accidents, and the sea transport is not a specially hazardous activity (see Table). Social response depends to a large extent on where the accident happened and which people lost their lives. For instance the historically largest sea disaster of the ferry DONA PAZ in which 4000 lives were lost, was scarcely noticed by mass media and did not practically trigger any reaction of public opinion because it occurred in the Philippines.

***Tab.** Frequency of lost lives per hour (FAR = Fatal Accident Ratio)*

Type of activity	FAR x 10^8	Type of activity	FAR x 10^8
All sea-going ships	11.8	Coal mining	40
Aviation – crews	~ 14	Car driving	70
Aviation – passengers	1.4	Ocean technology	76
Agriculture	10	Mountain climbing	4000
Sea fishery	35	30-year-old man-all hazards	15

The risk R is defined as the product of the accident probability (or frequency) P and its consequences C, i.e. R = P x C. To determine a tolerable risk level the ALARP rule (i.e. As Low As Reasonably Practical) is usually applied. The application method of the rule is highlighted in Fig.5.

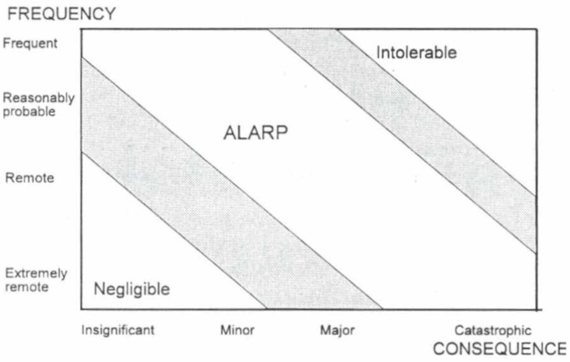

***Fig.5.** ALARP rule application scheme*

Organization

A significant number of accidents is caused by unsuitable management or organization. Bad organization can be identified as lack of : control, procedures, organizational aids, activity of maritime administration, safety management policy, motivation.

The organizational problems have been noticed by IMO and just recently the above- mentioned Safety Management Code adopted. Adoption of the Code closes, in a sense, a gap in the maritime safety regulations and also it should undoubtedly contribute to increasing the ship safety with respect to stability, though the Code itself directly does not refer to ship stability.

Human being

Operator errors are the most frequent cause of accidents at sea. There is a tendency to hold the operator responsible for accident since human error is easily noticeable. However usually an accident results from the coincidence of operator's and organization errors. Moreover operator's actions depend to a large extent on individual features of the human being, and also depend on environment conditions. The long list of the operator error causes was put together, namely : tiredness, negligence, unawarness, jealousy, arogance, wishful thinking, wrong assessment, bad intention, slowliness, laziness, boredom , physical limitations, alcohol, narcotics, disrespect, lack of qualifications. Of course the list is not full.

The human errors become more serious and frequent in circumstances of stress and panics and dramatic situations. The factors which influence decisions of the operator are : mental predispositions, physical predispositions, character, morale, reliability, knowledge and experience, training level.

The influence of personnel selection and training on the crisis situation management is illustrated schematically in Fig.6 [7].

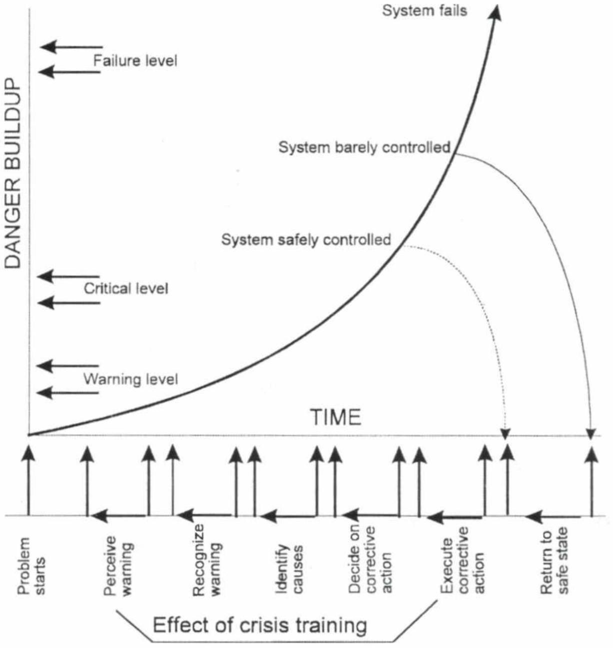

***Fig.6.** Crisis situation management in conditions of hazard growing with time*

Operator's reaction in a critical situation can be divided into three phases : warning – decision consideration – action. A system cannot be controlled if the decision is erronous or taken too late, or assessment of the situation is not correct. The human errors cannot be eliminated entirely, but training, qualifications and experience of the operator can drastically lower their number.

System

The safety system with respect to ship stability consists of such elements as : design standards, operational stability, stability control, information on ship's stability, weather forecast and information. Also, the design features of the ship and cargo securing means belong to elements of the system.

The designed ship stability, similarly to the operational one, should comply with the requirements determined by the standards. However, possible controlling the ship stability in service is an important element of the system. Information on the current stability characteristics during voyage makes it possible to correctly assess ship's safety.

The weather forecast and information is a very important element of the safety system with respect to stability as it makes possible taking a correct tactics by the ship master to avoid bad weather.

The safety system with respect to stability also comprises the formal safety assessment (FSA) which itself can form a basis for elaborating more rational stability standards. FSA contains hazard identification, overall risk assessment, allowable risk determination, determination of safety requirements on this basis, and safe operation conditions [10]. This is however a separate problem out of the scope of this paper.

STABILITY CONTROL OF THE SHIP IN OPERATION

In [11] various methods of operational stability control are thoroughly described. All the methods can be divided in to two groups : those using the calculations based on cargo data, and those making use of the devices which can measure real stability characteristics. The first group can be further divided into the methods which use individual means (calculations performed by hand , using calculator or personal computer) and those where special devices are applied to determine current stability characteristics (mechanical and electromechanical instruments, electronic simulators, loading control computers).

All calculation-based methods, both those using individual means and special devices, utilize data on location of the centre of light ship mass and on values and distribution of mass components of cargo and ballast. Therefore they contain the error resulting from inexactness of such data. In particular the light ship mass and location of its centre changes with age of the ship ; they also change during ship voyage due to consumption of supplies. All devices of that kind merely make determining the stability characteristics easier, however they do not make possible to exactly determine it during ship voyage.

Several types of the instruments based on measuring some ship parameters during voyage or before ship departure are available. The measured parameters can be : rolling amplitude, rolling period, acceleration or heeling moment (induced by changing distribution of water in tanks or by other means). The simplest method is to measure rolling period just before starting the voyage. The method, though advised by IMO, is not very exact due to uncertainty in determining mass inertia of the ship. The standard inclining test belongs to this category of methods, but usually it is carried out during the delivery of the new- built ship or for the ships after major repairs, conversions or modernizations. In [12] the inclining test was proposed to be carried out before starting every voyage, and called the operational inclining test (OSI) (Fig.7). OSI makes it possible to determine the operational ship stability more exactly than in the case of calculations.

This very simple method which does not demand any additional aids is worth advising.

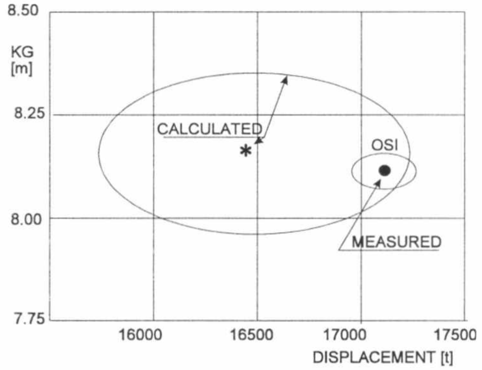

Fig. 7. Example of the operational inclining test (OSI) results

INFORMATION ON STABILITY FOR SHIP MASTER

Both SOLAS and LL convention, demanding to provide the ship master with the information on ship stability, do not determine however the scope and form of it. IMO A.167 (ES.IV) Resolution provides more detail guidelines as regards the information, similarly to the recently adopted IMO Intact Stability Code (IS Code - A.749 (18) Res.). It is obvious that having the information onboard is very important for safe operation of the ship. The information should be so elaborated as to make obtaining the necessary data as simple as possible which is of special importance in critical situations. IMO working program still contains the problem of preparation method of the information on ship stability. The work covers, apart from the traditional booklet form of the information, also application of various instruments as well as the computer.

However another aspect related to the information exists. This is information on navigation methods in heavy weather. The ship master should take the tactics of possible avoiding the extreme weather conditions which could lead to critical situations. To follow this way he should be provided with the long-term weather forcast obtainable from meteorological services. Such sevices already operate on most sea and ocean areas. However accuracy of their forcasting could be a problem.

If the ship moves in rough seas her master should take the tactics of avoiding a dangerous combination of the heading angle in respect to waves, and speed. The danger can consist in excessive (resonance) rolling, slamming, shipping of water, loss of steerability etc. Recently IMO adopted a reccomendation in the form of the diagram which makes it possible to quickly determine dangerous combinations of the ship course and speed (IMO, MSC Circ. 1995). However it is merely the first step in the direction, and the computer systems making it possible to simply and quickly assess ship situation in heavy seas are expected to be applied in the future. Such proposals have already been presented, see for instance [13] and [14].

It seems that in the near future the information on ship stability for the ship master would be much more developed. For future large sea-going ships, especially fast craft, the method applied in civil aviation could be very effective. A respective proposal was already submitted [15]. In accordance with it the information should contain : instruction for pilot, operation instruction, routing instruction, shipping instruction.

TRAINING

The influence of operator's training and competence on the safety of systems is well known. Nevertheless the STCW Code [International Convention on Standards of Training, Certification and Watchkeeping for Seafarers] recently adopted by IMO, which contains minimum qualification standards for ship masters and navigation officers, enumerates only three elements related to ship stability :

- ❖ understanding the principles of ship construction, theory of and influencing factors on ship trimming and stability, as well as the means necessary to maintain ship trim and stability
- ❖ knowledge of the influence of damaging and, in consequence, flooding of a ship compartment on her trim and stability as well as of the remedies to be taken
- ❖ knowledge of IMO recommendations for ship stability.

This is, of course, not sufficient as no special training is required as regards stability, like that provided e.g. for ship manoeuvring.

It seems that special courses on ship stability should be organized, perhaps with the use of simulators of ship motion in rough seas. Such simulators do not now exist, but there is nothing against building the instruments in the future as the background for their possible applications exists. It is important however to make them able to simulate critical situations as controlling such situations should be the basic element of the training in question.

BIBLIOGRAPHY

1. Kobyliński L.: „Safety of Ships Against Capsizing". Thrid IMAEM Congress, Athens, 1984
2. Foy D.B.: „Marine Enquires and the Public Interest". Trans. Imar. E(C), 1982, Vol. 95
3. Krappinger O., Hormann H.: „Problemstellung und Losungssatze". STG Jahrbuch 1984
4. Kobyliński L.: „Philosophische und Hydrodynamische Probleme der Kenterkriterien von Schiffen". Int. Schiffstechnisches Symposium, Rostock, 1984
5. Kastner S.: „Operational Stability of Ships and Safe Transport of Cargo". Third STAB'86 Conf., Gdańsk, 1986
6. Manum I.A.: „What have guided international activities on intact stability so far ?". Fourth STAB '90 Conf., Naples, 1990
7. U.S. Coast Guard : „Prevention Through People". Quality Action Team Report, 1995
8. Kobyliński L.: „Possibility of Application of Safety Assessment to Stability Criteria". U.S. Coast Guard Sability Symposium, New London, 1993
9. Payer H.G.: „Schiffsichercheit und das menschliche Versagen". Hansa, 1994, Vol. 131
10. IMO : „Formal Safety Assessment. Draft Guidelines for FSA". Doc. MSC 67/13, 1996
11. Lipis V.B., Salov V.Y.: „Problem of the Stability Control of Transport Ships in Operation". Fourth STAB'90 Conf., Naples, 1990
12. Kaps H., Kastner S.: „On the Determination of Ship Stability during Service". Fourth STAB'90 Conf., Naples, 1990
13. Nechaev y., Degtyarev A., Boukhanovsky A.: „Analysis of extremal situations and ship dynamics in seaway in an intelligent system of ship safety monitoring". Sixth STAB'97 Conf., Varna, 1997
14. Kleijweg R., Bussum B.V.: „Experience with on board computer system for stability and strength : objectives for the coming years". Sixth STAB'97 Conf., Varna, 1997
15. Jullumstroe E.: „Stability of High-Speed Vessels". Fourth STAB"90 Conf., Naples, 1990.

Appraised by Stanisław Gucma, Assoc.Prof.,D.Sc.