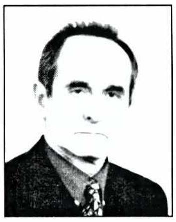

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On feasibility of the free-fall lifeboats for safe evacuation of marine accident casualties

SUMMARY

In this paper an attempt is presented to analyze real possibilities of safe evacuation of the casualties of marine accidents with the use of the Free-Fall Lifeboats (FFL). Major impediments are discussed and proposals of the relevant amendments to the current regulations are outlined.

The influence is analyzed of the dynamic behaviour of the FFLs on the casualties placed on a stretcher and differently located within the lifeboat. On the basis of the evacuation scenario some practical conclusions have been worked out leading to recommendations for safe evacuation of the casualties of marine accidents.

INTRODUCTION

Although casualties are an obvious aftermath of disastrous events at sea, evacuation of the casualties is still at the far end of the agenda of maritime legislative bodies. Except of some recommendations aimed at aiding disabled persons on board passenger vessels in the emergency conditions, the procedures regarding evacuation of the casualties off any other merchant vessel do not exist despite substantial progress in lifesaving technique. On the other hand, even having appropriate rules would not help as the lifesaving appliances are not adapted to serve the casualties [1] , [2] and [10].

Implementation of the FFLs has substantially reduced the risks connected with conventional lifeboat by allowing the Free-Fall Lifeboat (FFL) to escape quickly from the dangerous zone around the damaged vessel.

Therefore FFLs have become a common lifesaving appliance on ships and offshore facilities. However, the manner of launching a FFL causes potential danger of an injury to its occupants if a proper position and protection of them are not ensured.

A research project was launched, aimed at improving the FFL performance and minimizing the risk of an injury to its occupants. The project resulted in working out a procedure for determining kinematics of the lifeboat and dynamic forces acting upon its occupants, thus making it possible to optimize the FFL performance in terms of launching height and passenger carrying capacity.

In [8] and [9] the analytical model of the launching process and computer simulation procedure combined with model tests were described.

Experimental verification of the numerical results based on model tests and measurements carried out on prototypes, as well as some practical aspects of FFL design and operation were discussed in [6], [7] and [9].

The procedure of launching simulation used during design stage makes it possible to improve the hull shape, to determine the proper position of the seats and to shape the seats so as to assure the minimum load exerted upon the lifeboat occupants.

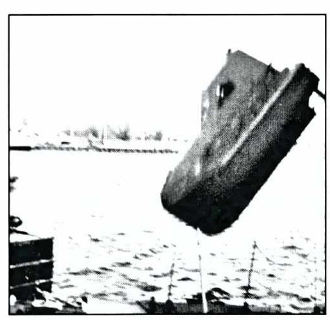

Fig.1. Free-fall phase of launching a FFL

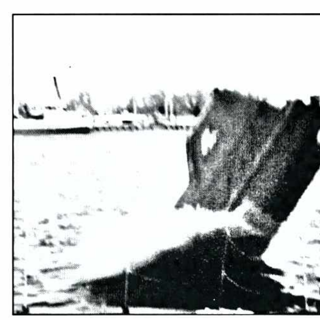

Fig.2. Water entry of a FFL – beginning of the self - righting motion

Fig.3. Last phase of FFL launching - inertial motion

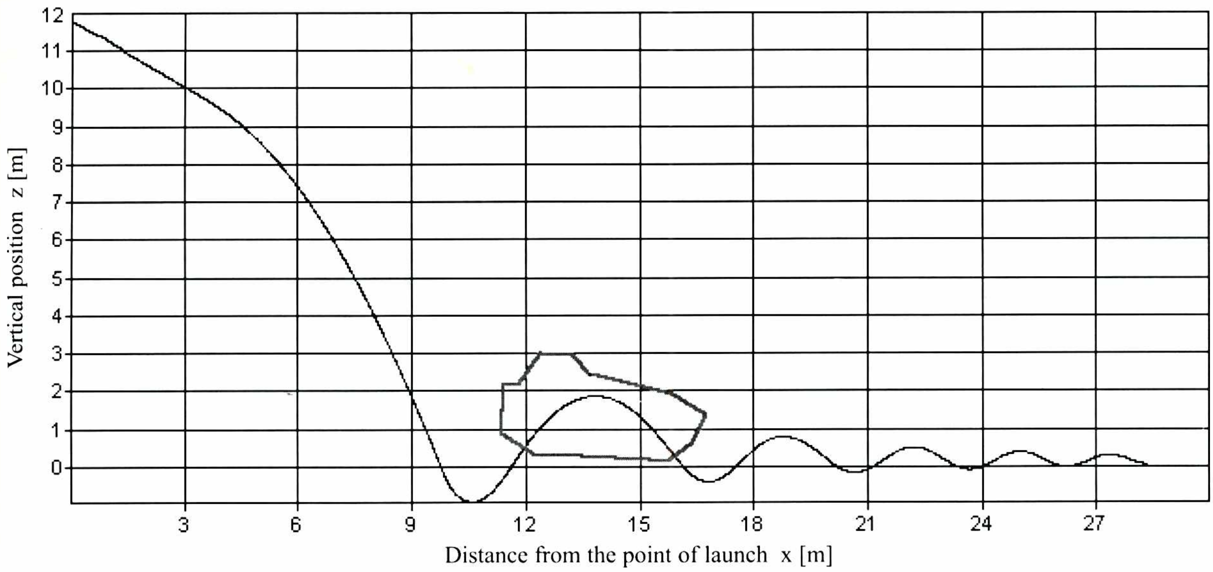

Fig.4. *Example of simulated launching trajectory of FFL centre of gravity .*
(Launching height : 12 m, centre-of-gravity coordinates : x_c=2,85 m, z_c=1,0 m; distance travelled in 10 s : 28 m)

During launching some scale models and FFL prototypes acceleration measurements, as well as observation of the ability of the lifeboat to make positive headway from its mother vessel were carried out.

Results of the numerical analysis, experiments carried out on a number of prototypes, as well as discussions with marine safety experts and national maritime board executives had directed the author's attention to the feasibility of FFL to safe evacuation of the casualties of marine accidents.

Review of the relevant IMO Resolutions and other marine safety regulations have indicated that little concern has been given to the problem in question. The insufficient concern for the human factor in the evacuation procedures was raised by Young and Eggleston [10].

The below presented approach is focused on :

- ➢ Determining to which extent the launching accelerations of a FFL would affect its occupants, especially those not placed in ordinary seats.
- ➢ Finding out if the potential of an injury of the casualties could be evaluated on the basis of the existing guidelines.
- ➢ Analyzing the evacuation scenario and its connection with the conditions for safe evacuation of the casualties.
- ➢ Working out relevant proposals for improving the existing guidelines, to assure conditions for safe evacuation of the casualties of marine accidents by means of FFL.

CURRENT REGULATIONS

The requirements concerning design, building and testing conditions of FFLs and safety of its occupants are specified in the IMO Resolution A.689 (17) [4]. According to it a FFL should be so designed as inertial forces induced by the launching process and acting upon the lifeboat occupants to be contained within an allowable range. The acceleration limits are expressed in terms of the *Dynamic Response Index* (DRI) i.e. weighed root mean square (RMS) of the components of the passenger's body displacement due to the launching accelerations.

$$\mathbf{DRI} = \sqrt{\left[\left(\frac{\Delta_x}{\delta_x}\right)^2 + \left(\frac{\Delta_y}{\delta_y}\right)^2 + \left(\frac{\Delta_z}{\delta_z}\right)^2\right]} \leq 1$$

where :

$\Delta_x , \Delta_y , \Delta_z$ - computed dynamic response components
$\delta_x , \delta_y , \delta_z$ - allowable values of displacement components.

In order to assure that dynamic response of the passenger body satisfies the above given condition, the passenger seats are properly positioned and shaped and the safety belts are provided to ensure the desired position of the person during launching of a FFL. Furthermore, the polyurethane-foam upholstery of specified vibration-damping properties is provided.

The aforementioned IMO Resolution also specifies detailed recommendations for the procedure of experimental determination of the launching accelerations, as well as parameters of the dynamic model to be used for computing the actual DRI resulting from the measured accelerations. Also, the allowable values of δ_x, δ_y, δ_z are specified in it, (Tab.1).

The same resolution allows for using another method to evaluate the severity of the dynamic forces. It consists in computing the *Combined Acceleration Response* (CAR - weighed RMS of the acceleration components), based on values of the measured accelerations (see Tab.2). The data necessary for both procedures were assumed on the basis of the results of the AFARL (US Air Force Aeronautical Research Laboratory) research [4].

Tab.1. *Allowable values of displacement components [4]*

Direction	Dynamic response δ[mm]	
	Test	Emergency
-x (to body)	68.6	87.1
x (off body)	61.6	87.1
y	40.9	49.5
z (off the head)	53.3	63.8
-z (to the head)	31.5	42.2

Tab.2. *Allowable values of acceleration components [4]*

Direction	Multiplier of gravity acceleration n [-]	
	Test	Emergency
-x (to body)	15.0	18.0
x (off body)	15.0	18.0
y	15.0	18.0
-z (to the head)	7.0	7.0

It should be noticed that :

- ✶ the recommended procedure applies only to the sitting position and
- ✶ the dynamic load limits recommended by [4] would most probably exceed the casualty's capacity to withstand such load.

LOCATION ANALYSIS

In order to find the location within the lifeboat, least dangerous for a wounded person, the relationship between the location of the disabled person on a stretcher and the launching accelerations should be analyzed. However, the regulations do not require carrying any kind of stretcher on board. Therefore, the below presented consideration is based on the assumption that the foldable flat stretcher is used to deliver the casualty to the lifeboat.

Three following factors should be considered :

- → Acceleration distribution over the length of the lifeboat.
- → Short time available to complete the boarding.
- → Limited space in the lifeboat for „manoeuvring" the stretcher and inconvenient inner arrangement of the boat.

The crucial moment of the launching process (regarding the acceleration history) is the beginning of the water-entry phase of motion (Fig.1÷3). The impact against the water surface induces a considerable peak of acceleration (Fig.5). Its component acting in the plane parallel to CL (Central Line), and perpendicular to it (z-component) is directed upward and the x-component (along CL) – opposite to the direction of motion.

New dynamic equilibrium conditions occur at the beginning of the water entry when hydrodynamic drag force begins to act, causing the point of application of the resultant force to shift. The latter generates the righting moment which in turn changes the primary direction of lifeboat's rotation. The lifeboat immerses and then emerges from the water propelled by inertia force and dynamic lift, still rotating about the lateral axis in a self-righting motion (Fig.4). This motion is accompanied with another peak of acceleration, acting mainly upon the after part of the lifeboat, as motion of its bow is damped by the water (Fig.4,5,6).

The z-component of the second acceleration peak is now directed towards the water. Therefore dynamic load exerted upon a person on the stretcher fixed in the after part of the lifeboat, would be different from that near the bow.

At the after part of the lifeboat two subsequent impulses act (x-component - both in the same direction and z-component in the opposite directions), usually for a fraction a second, causing the load severity higher than that at the position closer to the bow.

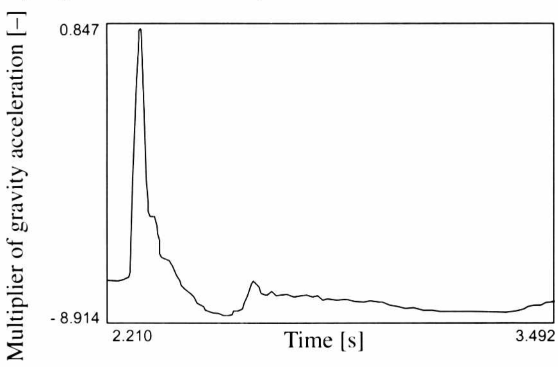

Fig.5. Acceleration history (x-component of acceleration) at the after part of the lifeboat [7]

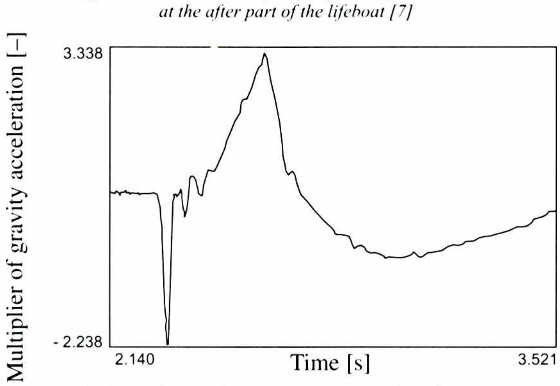

Fig.6. Acceleration history (z-component of acceleration) at the after part of the lifeboat [7]

That effect appears specially severe in the lifeboats of the length-to-width ratio less than 3. By inclining the seat rest, exposure of a person sitting on an ordinary canopy to the inertia forces threatening with the spine injury, would be decreased (to a fraction of the z-component of acceleration). A detailed analysis of that relationship was presented in [9].

For these reasons it would not be recommended to place the casualty at the after part of the lifeboat. On the other hand, it would not be also recommended to place the wounded person at the fore part because of a short time allowed for boarding the lifeboat and limited space within the lifeboat, as well as the need to avoid hindering the evacuation. Hence, neither fore nor aft position would be recommended for safe evacuation of a casualty on a flat stretcher.The short time interval between the first and second impulse (higher acceleration rate) additionally deteriorates the situation.

Therefore further consideration should be given to the relationship between shape of the seat and magnitude of the acceleration components acting upon the passenger' body.

The acceleration **a** (Fig.7) can be split into two components in the directions defined by the passenger position. Is it a seat, the components are : $\mathbf{a'_x}$ and $\mathbf{a'_z}$. In the case of a flat stretcher they would be respectively : $\mathbf{a_x}$ and $\mathbf{a_z}$. Comparison of $\mathbf{a_z}$ and $\mathbf{a'_z}$ indicates that the first one is significantly greater, i.e. a person on the stretcher is subject to a higher acceleration perpendicular to the spine, which means higher spinal injury potential for a person on a flat stretcher, against that in the ordinary canopy.

On the other hand, the flat stretcher is not fitted with a protective layer for absorbing the impact energy, as are the original seats in the lifeboat. Hence the impact energy exerted upon the human body would be respectively higher. Therefore, the aforementioned DRI criterion can not be applied to evaluate the injury potential of a person on a flat foldable stretcher. The CAR Index can not be used as well for the earlier explained reason. On the other hand, the disabled person's capacity to withstand the dynamic forces is smaller than that of the physically fit, which means that the forces should be respectively smaller than those specified in [4]. The above outlined considerations indicate that the casualty should be transported by means of another type of the stretcher, i.e. such that would make another position of the casualty possible.

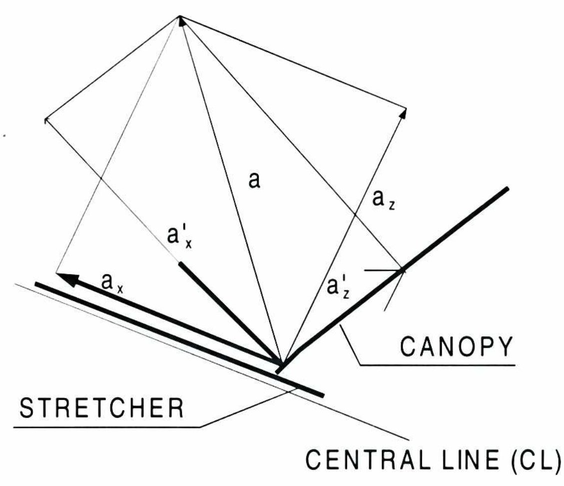

Fig.7. Acceleration components acting upon a person on the flat stretcher and in the canopy :
a_x, a_z - measured acceleration components
a_x', a'_z - acceleration components reduced to the seat rest axis

EVACUATION SCENARIO

With quickly growing number of FFLs installed on board seagoing vessels, the probability of using these lifesaving appliances in the emergency conditions increase.

The necessity to use a lifeboat occurs in the case of such disaster as : e.g. damage of the vessel, fire on board, leakage of a chemical medium dangerous for the crew. The prevailing number of the accidents results in the casualties who have to be evacuated with the help of those still capable to do it, usually by means of a stretcher.

While planning an efficient evacuation
the following questions should be answered :

- How to deliver the disabled person to the lifeboat ?
- Which type of the stretcher should be used ?
- Which is the best location of the stretcher within the lifeboat ?
- Which additional precautions are necessary to assure safety of a person on the stretcher ?

If it is necessary to evacuate a casualty, two crew members put he wounded person on a stretcher (usually of the flat type) and carry he stretcher to the lifeboat. As the FFLs are installed above the main leck the group should climb up the stairs.

On the way upward the disabled person should be carried with he head at the front of the stretcher. When the group approaches the :ntry to the lifeboat it should turn the stretcher by 180° to position the)erson on the stretcher face-to-the-stern (Fig.8).

With little space available, such manoeuvre requires some time ınd considerable skill.

The position of the lifeboat inclined by 30÷35° to the deck makes he task even more difficult. This applies to any type of the stretcher.

To let the whole crew board the lifeboat in a short time, the :asualty should be brought last (except of those carrying the stretcher) ınd the stretcher should be placed possibly close to the entrance. Thus, he two crew members and the casualty on the stretcher would not :ause a delay of the embarkation.

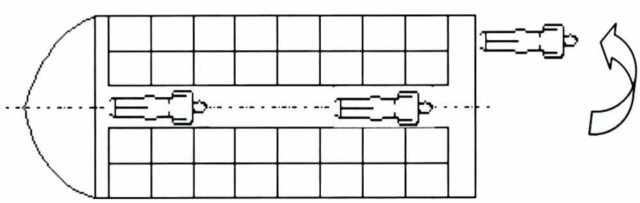

Fig.8. *Last phase of evacuation – situating a stretcher in the lifeboat*

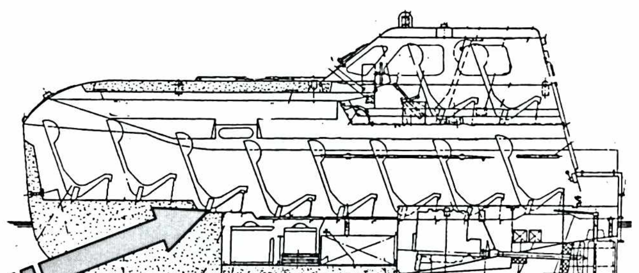

Fig.9. *Longitudinal section of a FFL showing the step-wise shape of the aisle, which obstructs positioning a flat stretcher*

Also, the manner of attaching the stretcher to the boat structure and that of the passenger to the stretcher should be considered.

It seems obvious that :

- the stretcher should be firmly attached to the lifeboat structure and
- the carried casualty should be properly fastened to the stretcher.

The fastening arrangement should be strong enough to resist
the inertia force of 10÷12 •(body weight) value.

If the stretcher allows for the sitting position, some of the aforesaid problems are no more important. Exposure of the casualty to the inertia forces is the same as that of the other lifeboat occupants. Only the disabled person's ability to withstand the load would be smaller.On the other hand, carrying a person in the sitting position over the ship communication routes and gangways would be extremely difficult, if possible at all.

CONCLUSIONS

Evacuation of the casualties of marine accidents by means of the FFL was analyzed from the point of view of dynamic load distribution as well as of the evacuation scenario. The analysis leads to the following conclusions :

- The obligatory procedures for evaluation of an injury potential of the FFL occupants, are inadequate to the situation of the persons with decreased capacity to sustain dynamic forces.Therefore it would be recommended to reconsider the allowable values of the DRI and CAR in such a way as to take into account the factor in question.
- An evacuation scenario should be prepared with accounting for the use of the FFL and indicating the location of stretchers and an arrangement to secure their position within the lifeboat.

The appropriate requirements should include
the following issues :

- to provide for at least one place in a lifeboat for a disabled person
- to assume the minimum required width of the aisle in the FFL to match the size of a stretcher
- to include a stretcher into the list of the mandatory lifesaving appliances
- to ensure correlation between the type of stretcher and the lifeboat design
- to add the casualty evacuation procedure to the list of the obligatory ship service documents
- to include the procedure into the marine officer's training requirements.

Appraised by Władysław Rymarz, Assist.Prof.,D.Sc.

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where :

EERTAG	- Evacuation, Escape and Rescue Technical Advisory Group
IMAM	- International Maritime Association of Mediterranean
IMO	- International Maritime Organisation
MSC	- Maritime Safety Committee
TEMPSC	- Totaly Enclosed Motor-Powered Surrival Craft