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FREE FALL LIFE BOAT HAZARD MEASURES

ABSTRACT

Between 1985 and 1992, at the NUTEC training facility in Bergen training launches at heights of both 28 meters and 12.5 meters took place. During this period sixteen injuries to personnel were sustained. It is not recorded if all the injuries were associated with a particular launch height and it is assumed that the injuries followed launches from both heights. It is noted that a higher number of injuries occur during on-board ship drills than during shore-based training. The Swedish submission concludes that, 'During the launch of the free-fall lifeboat, there is a potential for the occupants to be injured'[1]. As a result of this accidents interesting topic for further research and development has become evident: evaluation of performance of a free fall lifeboat in a wind and wave environments. In the paper the stochastic model of wave influence on the free fall lifeboat trajectory is presented.

Keywords:
lifeboat, free fall, hazard.

INTRODUCTION

According to IMO directives the launching appliance for a free-fall lifeboat must be designed and installed so that:

- the launching appliance and the lifeboat it serves operate as a system to protect the occupants from harmful acceleration forces and to effectively clear the unit;
- its ready to launch position, the distance from the lowest point on the lifeboat it serves to the water surface with the unit in its lightest seagoing condition does not exceed the lifeboat's certificated free-fall height;
- it preclude accidental release of the lifeboat in its unattended stowed position;
- the launching appliance must be capable of launching the lifeboat against unfavorable conditions of list of 5 degrees in any direction.

[1] Measures to Prevent Accidents with Lifeboats, Comments on evaluations of occupant seats, seating space and the adequacy of current design criteria for free-fall lifeboats, SUB-COMMITTEE ON SHIP DESIGN AND EQUIPMENT, 48th session Agenda item 5DE 48/5/10, 21 December 2004.

Table 1. Example of free fall lifeboats technical parameters,
Montomontaża Greben Shipyard, Croatia, www.greben.hr

	Loa (m)	Boa (m)	Hmax (m)	Mass empty	Mass loaded	Person capacity	Launching height	Launching system	
								HFF	HFL
FFL 12	5,60	2,45	2,80	2300	3200	12	12	12	12
FFL 16	6,12	2,70	3,35	3425	4625	16	14	16	16
FFL 19	6,92	2,70	3,35	3725	5150	19	16	19	19
FFL 28	6,85	3,10	3,55	3545	6045	28	14	28	28
FFL 32	7,65	3,10	3,55	4650	7050	32	16	32	32
FFL 40	9,25	3,10	3,55	6070	9070	40	20	40	

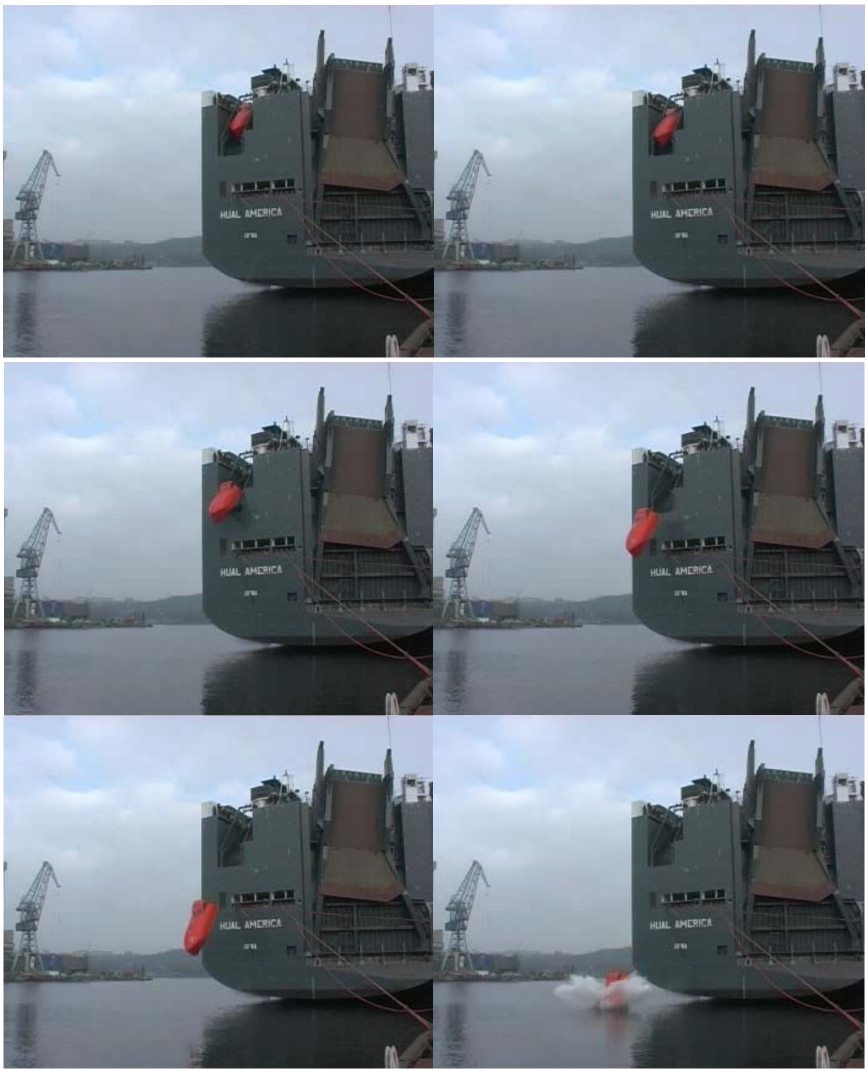

Fig. 1. The free fall lifeboat launch

Considering the trim and the pitching motion of the ship i.e. the stern point Q of the ship raises, the trim angle and the momentum pitch angle we obtain the following equation that express the trajectory of the stern point:

$$z(t) = -\frac{x^2}{4l\left[\sin(\Theta-\varphi-\psi(t)) - \mu\cos(\Theta-\varphi-\psi(t))\right]\sin^2(\Theta-\varphi-\psi(t))} - \frac{x}{\tan(\Theta-\varphi-\psi(t))},$$

where: Θ — the ramp angle;

φ — the trim angle;

$\psi = \psi(t)$ — the momentum pitch angle.

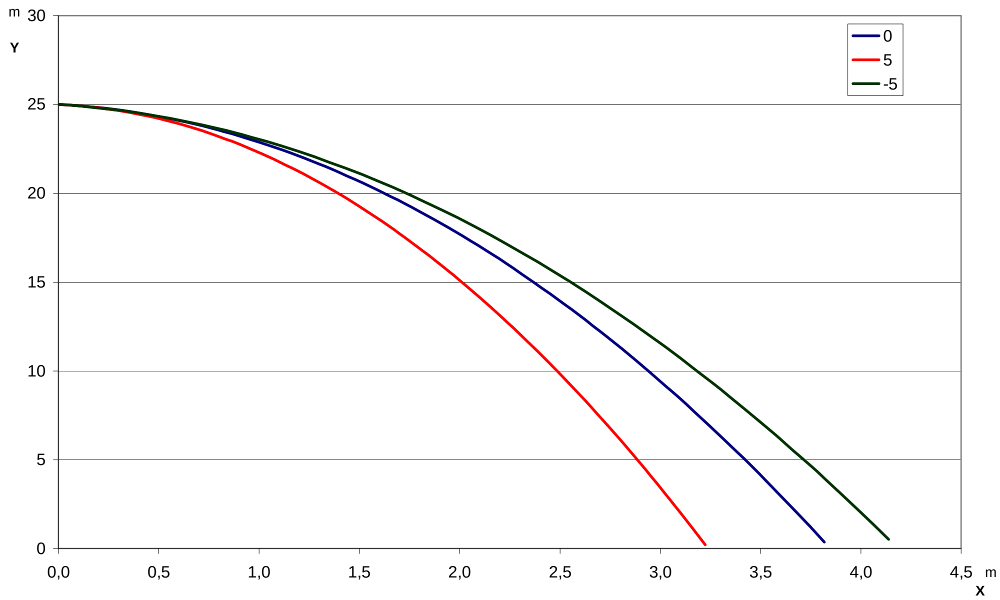

Fig. 2. The example of trim influence on free fall lifeboat trajectory

FREE FALL LIFEBOAT KINETICS

In launch kinetics it is the overall behavior of the boat which is of interests specially the trajectory taken and accelerations experienced by the boat [1]. The lifeboat can be treated as a rigid body (with appropriate mass and inertia) with forces applied representing interaction with the launch ramp, gravity and interaction with water [2]. To understand the mechanisms involved it is convenient to consider four stages of lifeboat launch:

- sliding along ramp;
- rotation at the end of the ramp;
- free-fall;
- water entry.

Sliding Along the Ramp

The equations of motion during this stage of the launch are:

- for vertical acceleration

$$\ddot{z} = -g \sin^2(\theta - \varphi - \psi) - \mu g \cos(\theta - \varphi - \psi)\sin(\theta - \varphi - \psi);$$

- for horizontal acceleration

$$\ddot{x} = g \cos(\theta - \varphi - \psi)\sin(\theta - \varphi - \psi) - \mu g \cos^2(\theta - \varphi - \psi),$$

where: μ — coefficient of friction between the boat and ramp;
θ — launch angle;
g — gravity.

From booth equations it can be seen that the boat accelerations during this stage of the launch are dependent on the launch angle and coefficient of friction between the launch ramp and boat but are independent of mass.

The Rotation Stage

The rotation stage starts when the centre of gravity of the boat passes beyond the end of the ramp. A turning moment is generated between the gravitational force acting at the centre of gravity and the reaction between the boat and the end of the ramp however the turning moment causes angular acceleration of the boat:

$$\begin{aligned} I\ddot{\theta} = {} & mg \cos(\theta - \varphi - \psi)[\cos(\theta - \varphi - \psi) + \mu \sin(\theta - \varphi - \psi)]\partial x + \\ & - mg \cos(\theta - \varphi - \psi)[\sin(\theta - \varphi - \psi) + \mu \cos(\theta - \varphi - \psi)]\partial z, \end{aligned}$$

where $(\partial x, \partial z) = (\partial x, \partial z)(t)$ — horizontal and vertical distance between aft and the center of gravity at time *t*.

The rotation stage ends when the boat leaves the ramp completely. The linear and angular velocities of the boat at the end of this stage will be dependent on the boat length aft of the centre of gravity.

Free-Fall Stage

The boat which has left the ramp is in free-fall. The only force acting on it will be gravity and the forces generated by cross winds. If we ignore the wind influence the boat will continue to rotate at the same angular velocity with which it left the ramp:

$$\theta_{end} = \theta - \varphi - \psi + \dot{\theta}_{\varphi,\psi} \cdot t_s ,$$

where: t_s — free falling time;

θ_{end} — angular velocity at the water entry;

$\dot{\theta}_{\varphi,\psi}$ — acceleration of angular velocity at the moment of leaving the ramp.

Water Entry Stage

As the boat enters the water forces are generated as the water is displaced by the boat. Neglecting the effects of surface tension the sources of these forces can be identified as:

- buoyancy effects;
- drag effects.

When the boat hits the water large drag forces are immediately applied to the boat. These drag forces decrease as the boat slows down. A large buoyancy force is generated which increases as the boat sinks into the water and peaks after the drag force. The boat rotates rapidly after initial contact with the water and a very large angular velocity and angular acceleration are generated. The boat rotates to a horizontal position in less than one boat length. The normal acceleration history shows two periods of negative acceleration at the aft of the boat. In the first instance this occurs due to the large angular acceleration experienced at the aft of the boat and in the second due to the boat falling back into the water.

During the work carried out by Frazer-Nash Consultancy Limited (FNC) for MaTSU on behalf of Offshore Safety Division of the Health and Safety Executive (HSE) under agreement Number MaTSU/8429/2866, the following characteristic of the launch is apparent from a launch height of about 20 m and launch angle of 350, the boat rotates through about 200 before water entry[2].

THE MODELS

Using the U.S. Department of Commerce, National Technical Information Service Lifeboat Analysis System (LAS), it was possible to predict the behavior of a freefall lifeboat deployed from a freefall ramp evacuation system located on a fixed platform into calm weather conditions[3]. Weather conditions were not a factor.

The most important factors for free fall life boat safety are the time of free fall stage, the angular and angular velocity at the moment of leaving the ramp. The time of free fall stage is given by the formula:

$$t_s = \frac{-\sin(\theta-\varphi-\psi)\sqrt{2l(\sin(\theta-\varphi-\psi)-\mu\cos(\theta-\varphi-\psi))}}{g} +$$

$$+\frac{\sqrt{2l\sin^2(\theta-\varphi-\psi)(\sin(\theta-\varphi-\psi)-\mu\cos(\theta-\varphi-\psi))+gH}}{g},$$

where: H — distance between end of ramp and water surfach;
l — ramp length;
g — gravity.

The distance between end of ramp and water surface can be expressed as a sum of two components:

h — the distance between end of the ramp and water level, deterministic;
h_{wave} — wave high, random with Weibull cumulative distribution function.

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[2] FEASIBILITY OF COMPUTER SIMULATION OF THE LAUNCH OF FREE FALL LIFEBOATS Frazer-Nash Consultancy Limited Shelsley House, Randalls Way Leatherhead, Surrey KT22 7TX, OTH 92 391, Health and Safety Executive - Offshore Technology Report, London: HMSO.

[3] National Research Council, Institute for Ocean Technology, Canada A1B 3T5, www.nrc-cnrc.gc.ca/institutes/iot_e.html

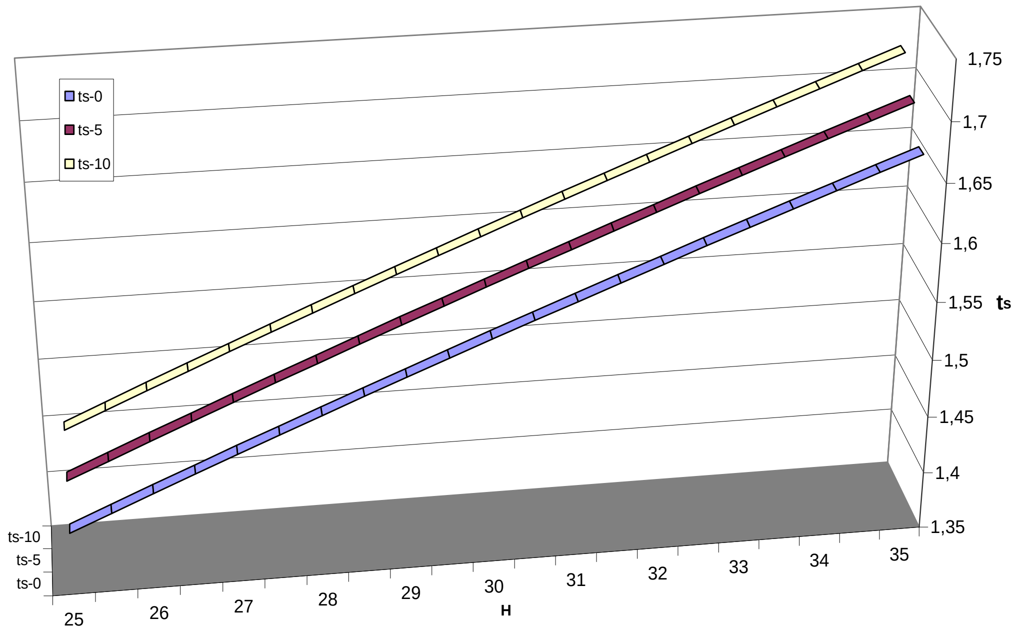

Fig. 3. The influence of the high H and trim on the time t_s

Under such assumption the distribution of time ts is expressed at:

$$F_{t_s}(x) = P\Big[gH < \left(x \cdot g + \sin(\theta-\varphi-\psi)\sqrt{2l(\sin(\theta-\varphi-\psi)-\mu\cos(\theta-\varphi-\psi))}\right)^2 + \\ -2l\sin^2(\theta-\varphi-\psi)(\sin(\theta-\varphi-\psi)-\mu\cos(\theta-\varphi-\psi))\Big];$$

$$F_{t_s}(x) = 1-\exp\left\{-\frac{1}{\alpha^\beta}\left(\frac{(x\cdot g+a)^2+b}{g}-h\right)^\beta\right\}, x \geq 0,$$

where:

$$a = \sin(\theta-\varphi-\psi)\sqrt{2l(\sin(\theta-\varphi-\psi)-\mu\cos(\theta-\varphi-\psi))};$$

$$b = -2l\sin^2(\theta-\varphi-\psi)(\sin(\theta-\varphi-\psi)-\mu\cos(\theta-\varphi-\psi)).$$

The angular velocity at the moment of entering the water is given by formula:

$$\dot{\theta}_{end} = \left\{ \frac{mg\cos(\theta-\varphi-\psi)\left[\cos(\theta-\varphi-\psi)+\mu\sin(\theta-\varphi-\psi)\right]\partial x}{I} + \right.$$
$$\left. - \frac{mg\cos(\theta-\varphi-\psi)\left[\sin(\theta-\varphi-\psi)+\mu\cos(\theta-\varphi-\psi)\right]\partial z}{I} \right\} \cdot t_s .$$

The trim angle is constant variable but the momentum pitch angle is a random variable with normal cumulative distribution function [5, 6], so the angular velocity at the moment of entering the water is random variable with probability density function expressed as:

$$g(z) = \int_{-\infty}^{\infty} f(x) h\left(\frac{z}{x}\right) \cdot \frac{1}{|x|} dx ,$$

where: $f(x)$ — the probability density function

$$f(x) = \frac{2\beta \cdot (x \cdot g + a)}{\alpha^{\beta}} \cdot \left(\frac{(x \cdot g + a)^2 + b}{g} - h \right)^{\beta - 1} \cdot \exp\left\{ -\frac{1}{\alpha^{\beta}} \left(\frac{(x \cdot g + a)^2 + b}{g} - h \right)^{\beta} \right\}, x > 0 ;$$

$h(z)$ — the probability density function of random variable

$$Y = \left\{ \frac{mg\cos(\theta-\varphi-\psi)\left[\cos(\theta-\varphi-\psi)+\mu\sin(\theta-\varphi-\psi)\right]\partial x}{I} + \right.$$
$$\left. - \frac{mg\cos(\theta-\varphi-\psi)\left[\sin(\theta-\varphi-\psi)+\mu\cos(\theta-\varphi-\psi)\right]\partial z}{I} \right\};$$

$\theta - \varphi - \psi$ — the random variable with normal probability density function expressed as

$$\phi(x) = \frac{1}{\sqrt{2\pi}\,\sigma} e^{\frac{-(x-\theta+\varphi)^2}{2\sigma^2}} , \quad -\infty \le x \le \infty .$$

Presented models can be used to construct reliability intervals for allowable values of important parameters like angular velocity at the moment of entering the water and the time of free fall stage [9].

CONCLUSIONS

The free fall lifeboat was developer in 1975. The free fall lifeboats have become one of the common types of lifesaving appliances on offshore facilities and ships. Current regulations do not explicitly state criteria for the maximum height of free fall at a particular installation and do not require the increase in free fall height caused by waves as same as the effects caused by list, trim or pitch of the vessel to be considered.

In the maximum free fall height on platforms the effects of waves and possible damage must be considered because the worst launch condition occurs when the free fall lifeboat is launched into the trough of a wave. So its necessary to determine accepted risk for evacuation of fixed platform according to return period and high of waves [4, 8].

For the ships task should focus of developing criteria according to acceptable level of risk taking into consideration vessels performance on waves. One of the principal causes of free fall lifeboat accidents appears to be influence of waves and wind which in many cases could change the lifeboat falling trajectory. Furthermore, it is clear that if the lifeboat enters the water with too small or too large angle the decelerations could be destructive either for lifeboat construction and for survivors [7].

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