Master Thesis in Marine Technology - 2017
Hydrodynamical effects relevant for free-falling lifeboats, in wave conditions

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ABSTRACT

Free-falling lifeboats are used as a last resort evacuating system for fixed and floating offshore installations.

It is a complex topic as it moves through different phases which contributes with different external loadings. There is essentially six different phases: launching phase, free falling phase, water entry phase, submerged phase, water exit phase and sail away phase.

The software utilized for preforming simulations with simplified geometry of a free-falling lifeboat is Star CCM+

A parameter investigation of impact velocity, water entry angle and z-position in center of gravity has been carried out. The largest effect on the behavior of the body is obtained by changing the impact velocity with $\pm$ 5 m/s. Changing the water entry angle with ± 5 ° also showed some effect, while changing the COG in z-direction showed lsmall effect.

To see the effect the wave will have on the behavior of the body, twelve cases is to be tested. Nine has been completed, and between these, the case where the body is entering in a crest in following waves seems to experience some of the largest accelerations and the shortest sailing distance. However, three cases have not yet been simulated. All of them are in head waves where the relative fluid-body velocity can be large.

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Objective and scope

1. Preform a literature study based on state-of-the-art works on numerical/experimental/theoretical studies relevant for the topic.
2. Preform a convergence check for a simulation of free-falling lifeboat, using a simplified geometry, in calm water conditions.
3. Use the simplified lifeboat geometry and preform a systematic numerical study on the parameters: Impact velocity, water entry angle and center of gravity position in z-direction.
4. Preform a numerical investigation of the influence of incident regular waves on the lifeboats behavior. Test for different wave heading and phases

Introduction

Free-falling lifeboat is used as a last resort evacuation system for fixed and floating offshore installations. The essential diving process is divided into six different phases:

1. It starts with the launch phase, where it slides down a skid
2. The free-falling phase, with an initial pitch rotation from the skid
3. The water entry phase, where the slamming forces are dominating
4. The submerge phase, where the formation and collapsing of an air cavity is an important feature
5. The water exit phase
6. The Sail away phase

The topic is complex, as the different phases contributes with different external loading.

Modelling

The software utilized for the CFD simulations is Star CCM+. They provide a helpful tutorial for free-falling lifeboats. A part called overset, is following the body as it moves through the different phases. This is computational economic, as it allows for finer mesh within this region. Several grids has been tested, and the final mesh configurations which were chosen for the simulations is shown in figure 1.
The body is an ellipsoid with length 10 m and maximum diameter 3 m.
The air has been modeled as incompressible. This is a simplification, as the eventually entrained air bubble will be compressible, which will affect the behavior of the body.

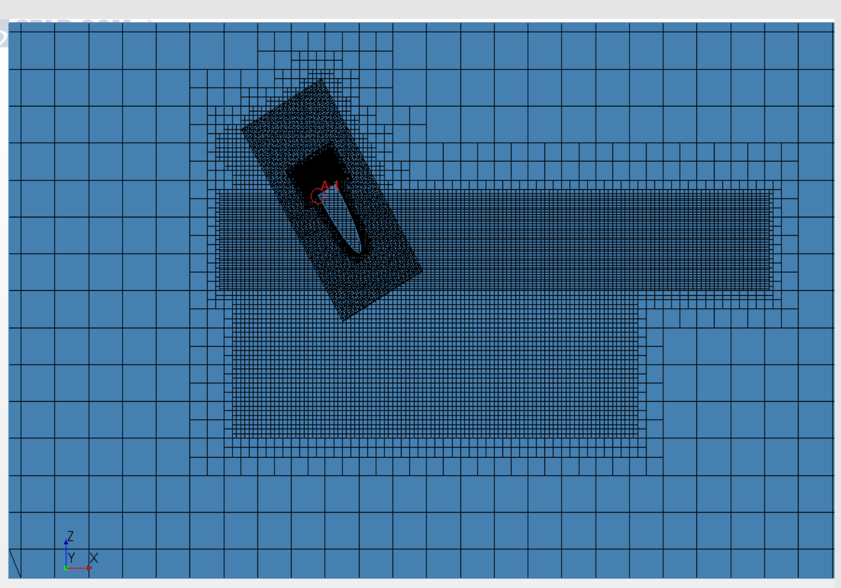

Figure 1: Chosen grid, with correct cell sizes

For the convergence check, three different mesh discretisation where tested. All the cases, except for the parameter investigation, were simulated with the initial conditions shown in table 1. For the parameter investigation, the velocity, water entry angle and COG in z were changed. For the simulations in wave conditions, twelve different cases where tested, four in following waves, four in head waves and four for beam waves. Within each heading, four different phases were tested.

Results

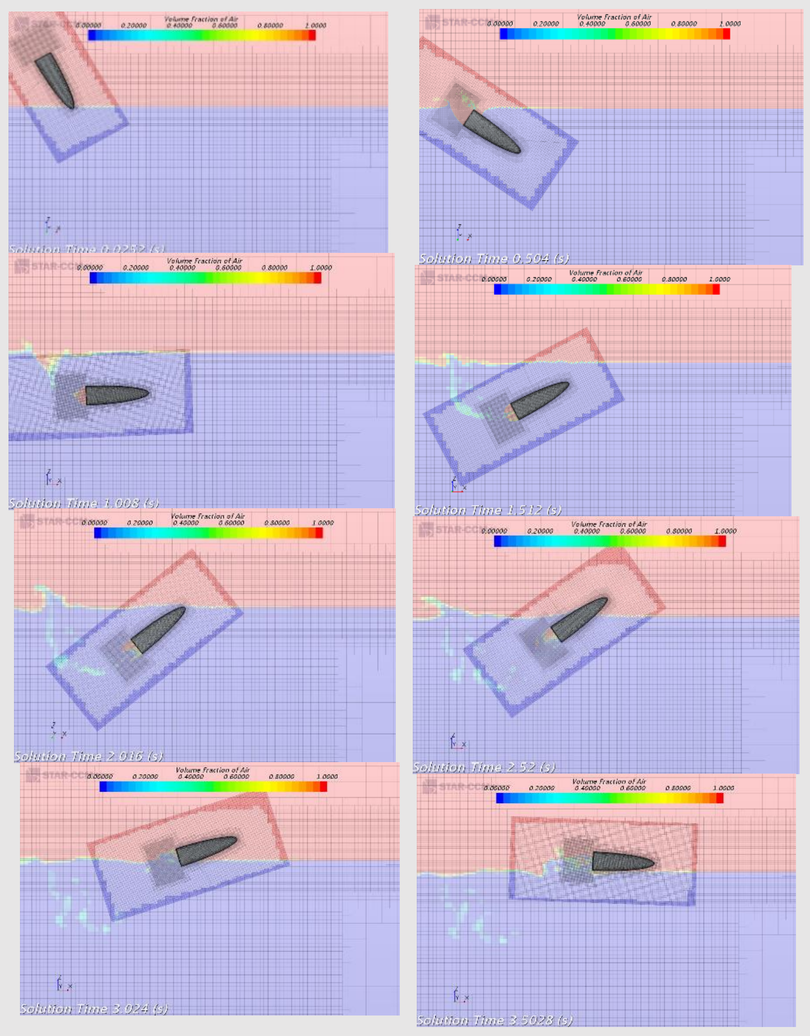

Figure 2. Volume of fluid (VOF) pictures of the simulation with initial conditions , red is 100 % air and blue is 100 % water

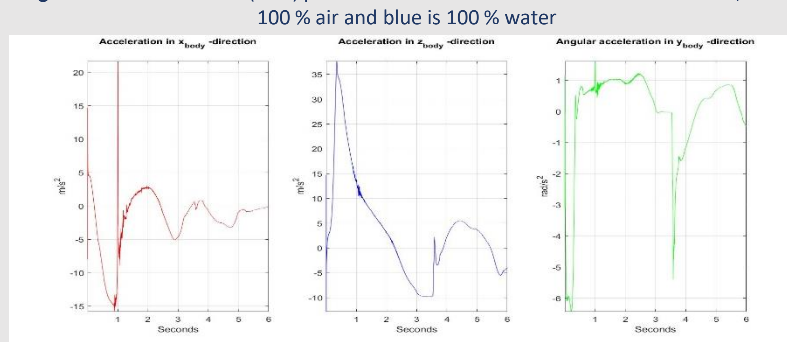

Figure 3: Acceleration in body fixed x- and z-direction and angular acceleration in pitch

The body is initially rotating with an angular velocity of 15 deg/s, clockwise. this velocity gets reversed at water impact, and the body gets a large acceleration in body fixed z-direction. An air cavity is forming after the aft part crosses the water surface. As the body continues the decent, the air cavity eventually collapses. The water is then pressing on the entrained air bubble on the aft of the body in the direction of motion. This is seen as the great peak at 1 s in x_{body} acceleration, figure 3. After air cavity closure, the body starts the ascent, driven by the buoyancy force. At the water exit the body shoots out of the water, flying through the air for a short period, before it re-enter the water surface and is subjected to a secondary slamming.

Parameter investigation

PARAMETER		-	IC	+	Δ
θ	[°]	55	60	65	5
COG_Z	[m]	-0.7	-0.5	-0.3	0.2
V	[m/s]	15.615	20.615	25.615	5

Table1: Parameter values θ is the water entry angle, COG_z is the center of gravity in z and V is the maximum velocity at water impact.

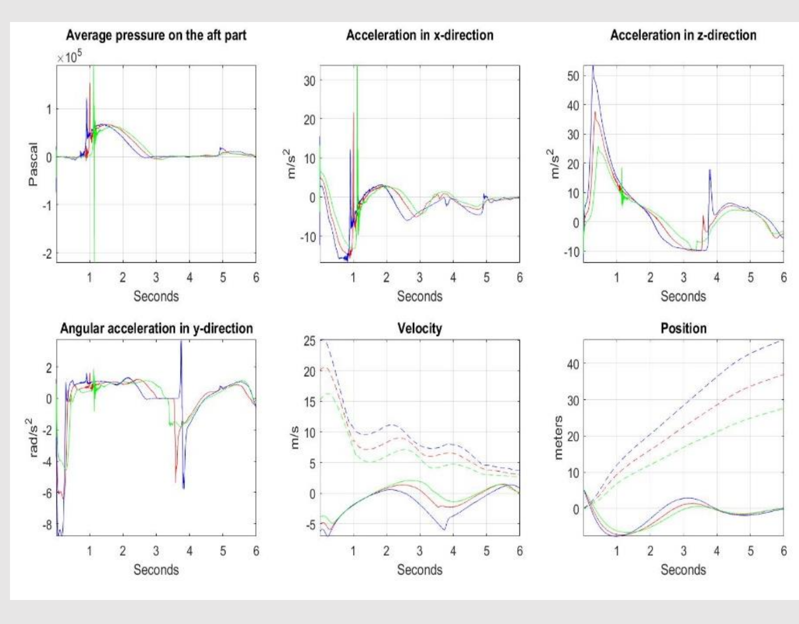

Figure 4: Parameter investigation result for velocity. Green is 15.6155 m/s, red is IC with maximum velocity 20.6155 m/s and blue is 25.6155 m/s. Solid line is x-direction and dashed line is z-direction

The greatest effect where apparent when the velocity was changed. The difference is revealed in figure 2. High impact velocity gives high counter clockwise rotation, which eventually leads to a large water exit angle and velocity. The large water exit velocity provides long sail away distance (position in x after 6 s). The behavior of the body where also affected by changing the water exit angle, but not in the same extent as by changing the velocity. Changing the COG_z showed small effect on the solution, the only noteworthy difference is the pop-up height, after water exit.

Waves

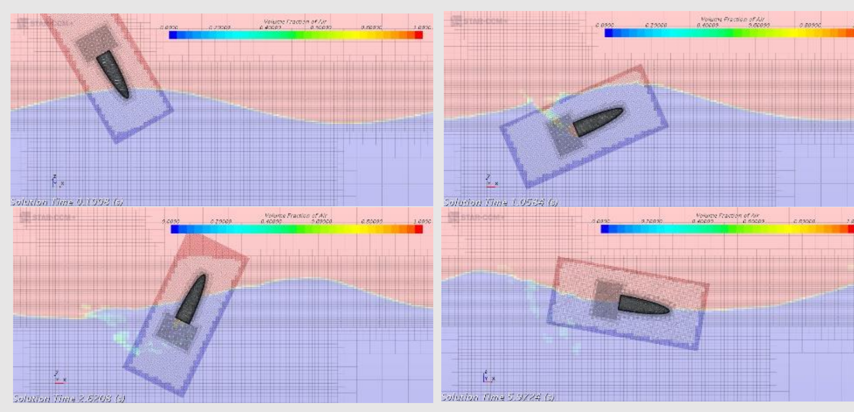

Figure 5. Volume of fluid pictures for hit point: wave crest, following waves

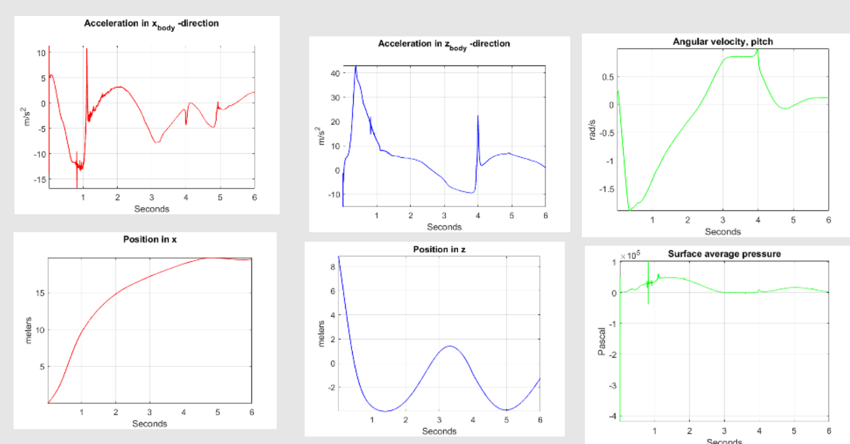

Figure 6: Results from diving in a wave crest , following waves

Three out of twelve cases in wave conditions has not yet been simulated. These are cases with head waves and will have large relative fluid-body velocities, and can contribute to large forces on the body.

Of the completed simulations, the case presented in figure 5 and 6 has one of the worst outcome. The body enters in a wave crest with following waves. The particle velocity in this phase is moving in the same direction as the propagation of the wave, and gives a large pitch velocity to the body, hence a large z_{body}acceleration. As the body gets slowed down, the aft part eventually gets in the wave phase where the particle velocity is acting downwards, pushing the aft part down and the body gets a large water exit angle. With low forward velocity in the x-direction, the body is eventually located in the wave trough, where it gets a motion toward the evacuation scene.

CONCLUSION

The parameter investigation shows that a velocity of $\pm$ 5 m/s shows larger effect on the behavior of the body than by changing the water entry angle with ± 5 °. The impact velocity and water entry angle is dependent on the diving height. When the body enters in a wave through or a crest, the diving hight can increase and decrease, respectively. The behavior of the body seem to have small sensitive for changes in center of gravity in z-direction with $\pm$ 0.2 m.

The waves have great affect on the behavior of the body, the forces and resulting trajectory of the body is dependent on which heading and wave phase it dives into. Diving into a crest in following waves leads to large accelerations on the body and short sailing distance.