SEAKEEPING BASIN TESTS FOR SURVIVABILITY AND EVACUATION OF SHIPS

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Abstract

The paper will describe the experience gained at the Seakeeping Laboratory of El Pardo Model Basin in the realization of model tests to assess the survivability of damaged ships in waves as well as to study the problems related to the ship evacuation systems in rough weather.

The different tests carried out include commercial tests to verify the compliance with Stockholm Agreement as well as research ones funded by the EU, the Cooperative Research for Ships (CRS) group and others. These research tests vary from the study of water motion in flooded spaces, transient flooding, roll motions, influence of initial and residual stability to the behaviour of evacuation systems (life boats, rafts or evacuation chutes) near the mother ship. The problems encountered, solutions and new instrumentation will be described.

1. INTRODUCTION

In the recent years a great effort has been dedicated to the study of the survivability of ships in damaged conditions, specially referred to ferries as, due to their large garage areas they are more affected by flooding. The interest for this field has been increased by the occurrence of fatal accidents like the Estonia sinking. Model tests at seakeeping basins are an invaluable contribution to these studies, both as a means to gain insight into the problem as well as to validate computer codes predicting the damaged ship behaviour.

The same increased concern for safety has resulted in the development of new and more stringent regulations concerning damaged ship stability defined in the, so called, Stockholm Agreement. These regulations ask for an improved behaviour of the ship in damaged conditions. Behaviour which shall be demonstrated either by deterministic calculations or by model tests. In many cases, ships, which will not pass an examination by the first method, will survive in the model tests. This has resulted in a lot of model tests being carried out, generating a large amount of data which could be very helpful in the future.

Another, related field, which can benefit from model tests is that of the evacuation systems. Again, the Estonia accident has raised questions about the safety of life boats and rafts as many of them failed during or just after release.

This paper presents a description of the possibilities for testing of survival and evacuation in seakeeping tanks like the Ship Dynamics Laboratory of the “Canal de Experiencias Hidrodinámicas de El Pardo” (CEHIPAR in the following).

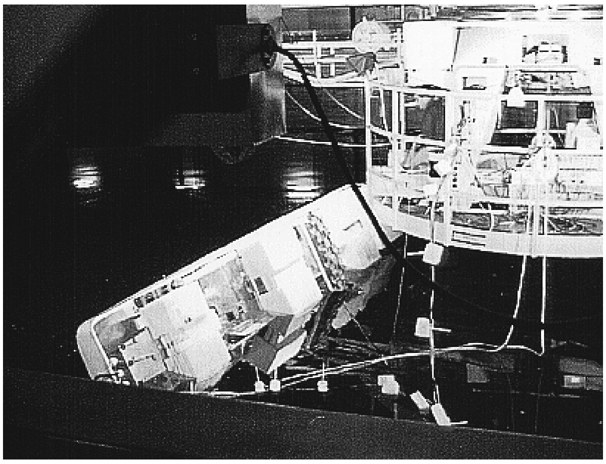

Figure 1. Model capsizing

It presents the experience gained in the realization of many tests, ones following Stockholm Agreement regulations and others for research and code validation. These research tests have been financed either internally, by the EU through its “Access to Large Scale Facilities” activity on the IV and V Framework programs (contract HPRI-CT-1999-00080), by Spanish Ship Owners or by the Cooperative Research for Ships (CRS).

Two EU funded research projects have been carried out at CEHIPAR. One directed by Dimitris Spanos from the National Technical University of Athens concerning water motions in flooded garage decks and damaged ship behaviour. The other was directed by the co-authors Elena Tsichkova and Philip Ekman from Chalmers University of Technology in Sweden, dealing with evacuation systems and water motions around a ship in waves. The Spanish Ship Owners tests have studied the influence of GM and freeboard in damaged ship survival. This question was also the objective of the CRS funded study as well as the question of transient flooding after damage.

In the following, the different kind of tests possible in the tank, the difficulties encountered and the way we have dealt with them are described.

2. THE SHIP DYNAMICS LABORATORY

The Ship Dynamics Laboratory at CEHIPAR is a large seakeeping and manoeuvrability basin located in Madrid. It is made up of tree main components: the basin, the wavemaker and the Computerized Planar Motion Carriage.

The basin has dimensions of 150 by 30 by 5 meters. A pit of 10 by 10 meters with a total depth of 10 meters is located near the wave generator for deep water tests. An adsorbing beach is installed on one side opposite to the wavemaker.

The wave maker is composed of 60 independent elements of the flap type hydraulically actuated. Its generation capabilities include regular and irregular waves, both short and long crested. Irregular waves can be as high as 0.4 meters significant height for a typical Pierson-Moskowitz spectrum.

The CPMC is composed of a main carriage running in the longitudinal direction (longest dimension) of the tank up to 5 m/s. A sub-carriage can run transversally below this main carriage up to 3.5 m/s. Finally a turret below the sub-carriage can rotate up to 30º/s. This set permits the realization of any computer controlled trajectory including forced oscillations of the model in the horizontal motions (surge, sway and yaw). A vertical oscillator with two degrees of freedom can be installed in the turret to perform forced oscillation tests in vertical motions (heave, pitch and roll).

Figure 2. The snake wavemaker

3. TYPES OF TESTS

Many different kind of tests can be carried out with the facilities available. As said before, according to their purpose, they can be classified into regulatory tests (Stockholm Agreement), pure research tests or code validation tests.

Another classification can be made depending on the type of physical model used:

- The model can be a 2D section of the ship or compartment for forced oscillation tests with water inside (sloshing tests).
- It can also be an intact ship or a damaged one.
- In between, there are tests with a model that although intact has a flooded compartment.

The model can be completely free or restrained in one or more degrees of freedom. The first case pretends to reproduce the most realistic situation like in Stockholm agreement tests, but many times, specially for code validation, it is preferable to isolate the different effects from each other and, then, restraining some degrees of freedom is a good solution.

Finally tests can be done with different objectives. For example their objective can be to study:

- Survivability
- Evacuation systems
- Wave
- Transient flooding
- Ship motions
- etc

Some aspects of these tests are discussed in the following.

4. MODEL TESTS REQUIRED BY THE STOCKHOLM AGREEMENT

The tests accepted by Stockholm Agreement [1] as an alternative to deterministic calculations are simple in its concept. They consist in reproducing at scale the damaged ship with all the compartments that can be affected by flooding, leave this model completely free in the tank and submit it to a given sea state to observe its behaviour in roll. If the measured roll does not surpass some specified values the ship is considered to be able to survive. But, what seems so simple at first glance, presents several practical problems when the actual test have to be done.

Some problems come from the fact that the regulation allows a lot of interpretation about how the tests have to be performed. And this is understandable as it is very difficult to pretend to take into account all the characteristics of the different ships and the different existing seakeeping towing tanks. This lack of definition is compensated by the requirement that the tests have to be surveyed and approved by the Administration, so that particular details of the test have to be agreed upon between the facility and the surveyors. However some help can be obtained from the guidelines established by the British Administration [2]

In the following we will discuss some of these problems and the way we treated them with the acquiescence of the Administration in charge of the survey.

4.1 Model construction

The regulation states that the shell thickness of the model shall be as small as possible. This is a “loose” definition but a reasonable one as the shell gives a maximum contribution to transversal area inertia. To this purpose we make the models in fibreglass with a minimum thickness of about 1.5 mm.

For the size of models we make which are around 5 meters in length with a weight of between 400 and 800 kg, this is a very low thickness for overall structural stiffness. Of course, we increase a lot the fibreglass thickness in the areas were no flooding can occur, but even so the model will be very weak in all the length occupied by the flooded compartments. This weakness would result in model deformations in the mode of sag, hog or torsions. Deformations which can have a large influence in the results of the tests as they can appreciably change the freeboard at the damage and this is a determining parameter in the ship’s survivability.

Longitudinal deformations (sag and hog) can be reduced by making the deck part of the supporting structure but this (which is assumed in the real ship) is not so easy in the model. Worse is the case of torsional deformations. The cross sections of the model in way of the damage are “open” and therefore their torsional stiffness is negligible.

We solve this problem by adding steel or aluminium longitudinal beams to the model. Normally we put these beams in the bottom through non flooded spaces like tanks in the double bottom.

Another problem with this kind of models is to guaranty that the empty spaces below the deck remain watertight. As, a priori, one does not know where ballast shall be put to get the correct weight distribution, we leave an opening on those spaces closed by transparent hatches so that their dryness can be visually inspected.

Vents and other air escapes, important to avoid unrealistic air trapping, can not always be modelled at scale. This is so because this could result in pipes as thin as 2-3 mm in diameter for which large scale effects can be expected. For this reason, and after some specific tests with different pipe sizes, we limit the vent diameter to a minimum of 8 mm.

4.2 Permeabilities

The permeabilities of each compartment according to IMO regulations have to be reproduced but there are no specific indications in the Stockholm Agreement on how this shall be achieved except that it has to be made by the addition of solid blocks. If one consider for example the garage deck where a 10% of volume has to be protected from flooding (90% permeability), it is clear that adding it to the sides has a beneficial effect that is non realistic. But putting it in the middle like if it were a (probably non existing) central casing, is again non realistic.

This is, of course, a question that has to be agreed upon with the surveying authority. The criteria we follow, accepted by the different authorities involved in the tests carried out at our facilities, is to distribute the additional volumes so that they fulfil the following limitations:

- The “blocks” go from the bottom to the top of the compartment.
- They cover an area *1-p* of the total area.

- Their transversal area inertia is also *1-p* of the total area inertia of the compartment.
- They are distributed so as to minimize their influence on the water flow.

Here *p* is the permeability after discounting the presence of constructive elements like hull thickness and others (e.g. main engines). To reduce the influence in the flow, the best is to add the volumes by increasing the width of lateral and central casings, if possible, while complying with the previous criteria.

In some compartments, like small tanks, it can be difficult to get the required permeability. Especially because bulkheads and decks cannot be made as thin as required by the scale. In those cases, small weights can be added in the correct position to compensate for the excess of floatability.

4.3 Weight distribution and natural period

The regulations ask for an inclination test both before and after damage. The test before damage has not special problems but trying to do it after damage can be difficult because the righting arm can change very quickly near the origin an even be asymmetric. This is especially true if the garage deck begins to be flooded at small angles.

For this reason, we consider that the GM has to be verified based on the intact inclination test while the damaged one serves only as a secondary check.

The regulations also ask to measure the natural period in the damaged condition because some of the tests have to be done with waves of such period (or $6\sqrt{H_s}$ whichever is less, H_s being the required significant wave height). This is normally done by the so-called roll decay test. The model is heeled to one side and suddenly released allowing it to oscillate in successively damped cycles whose amplitude is recorded. The natural period is then measured as the mean time between successive crests or troughs. Regretfully, when the model is in damaged condition the damping tends to be so high as to make it near critical in some cases (see for example Fig. 3) so that one gets only one cycle in the best of the cases making the previous procedure inapplicable.

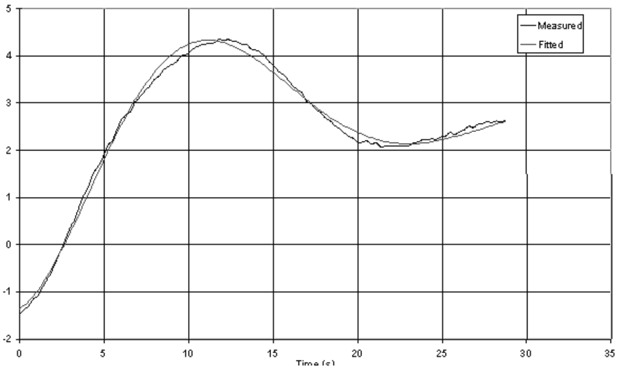

Figure 3. Roll decay test

In those cases we use still the roll decay tests but we analyse it in a different way. The procedure is to fit a four parameter function corresponding to the theoretical linear damping decaying motion to the data:

$$\phi(\phi_o,\tau,T_0,\alpha)=\phi_o e^{-\frac{t}{\tau}}\sin\left(\frac{2\pi t}{T_0}+\alpha\right) \quad (1)$$

where ϕ_0 is the initial amplitude, τ is the time damping constant, α is a phase and T_0 is the damped natural period of interest.

The function fitting is made by means of a non-linear least squares algorithm.

4.4 Instrumentation

The instrumentation required by this regulation is very simple if compared with other typical seakeeping tests. It, mainly, reduces to measure the motions of the model (especially roll) and the incoming wave.

For the last one we use a resistive wave probe located sufficiently forward or aft of the model so as to not be affected by reflections. For the motions we use an optical tracking system, which gives the motions in the six degrees of freedom with a very good precision. The system consist in three infrared linear cameras looking to, at least, three diodes put on the model in a calibrated configuration.

The cameras and the wave probe are installed on the carriage, which follows the slow drift motion of the model. This allows also recording the drift speed (another requirement of the regulations) as the sum of the carriage speed and the relative motion of the model to the carriage.

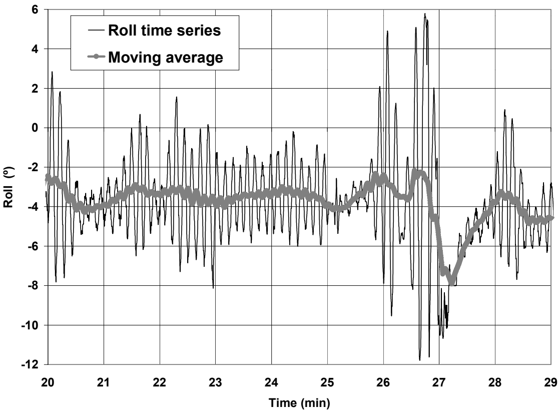

Figure 4. Example of measure and filtered roll

The regulation also says that an internal camera shall be installed in the case that barriers are fitted in the garage deck, to allow the observation of the possible water flow over them. Our practice, however is to always install at least an internal camera to observe the flow on the compartment. This has demonstrated to be very useful in helping to correct survivability problems. Sometimes, when the model does not comply the maximum heel and roll condition (it capsizes), the problem can be solved adding transversal barriers in certain positions. The observation of the video records gives, in these cases, invaluable information on where to put them so as to avoid dangerous water accumulation.

Finally, we have observed that the cables going to the model can affect its motions especially when the stability is marginal. For this reason, we changed our initial procedure of hanging an umbilical vertically from the carriage to the model to a floating umbilical attached to the stern of the model at the waterline.

Now, we are in condition to suppress completely the umbilical. Both, the video cameras and the motion measuring diodes can be controlled by radio and powered by batteries.

4.5 Test realization

According to the regulation the tests have to be carried out with the model completely free to drift. In the tests we already carried out it was observed that the model remains almost abeam to the seas while the drift speed in the transversal direction can be as high as 0.8 m/s and in the longitudinal direction up to 0.25 m/s, although this depends very much on the ship forms, dimensions and damage disposition.

For such drift speeds and considering the minimum allowed scale of 1:40, the tank has to be at least 36 m long and 12 meters plus the ship length wide. While for the typical scales of 1:25 used at CEHIPAR at least 60 m by 20 m are needed.

If the tank is narrower a means to reduce longitudinal drift has to be devised. This has to be made very carefully because any external force can appreciably affect the results. An example is given in Fig. 4 where a model was pulled back by a rope attached in the stern at the waterline to avoid bumping against the lateral wall. As a consequence an additional inflow of water has occurred and the heel increased suddenly from 3 to 8 degrees.

4.6 Analysis of results

Two criteria have to be fulfilled in order to consider the ship as non capsizing:

- 30º of maximum roll shall not be exceeded in more that 20% of the roll cycles.
- The steady heel has to be less that 20º.

Concerning the first criteria, we use a zero crossing method which detects the roll cycles and their maximum values to port and starboard. The criteria is then compared against the observed frequencies of exceedence separately for each side. When doing the zero crossing analysis it is customary to discard cycles whose amplitude is too small, so that small ripples or noise does not increase artificially the number of cycles and so reducing the exceedence probabilities. At CEHIPAR, following the practice of oceanographers when analysing time series of wave elevation, we discard any cycle whose amplitude is less than 5% of the standard deviation of the roll series.

With regard to the second criteria, it is not clear what “steady heel” means as the ship is continuously rolling. We, in agreement with the surveyors, have defined the steady heel as the moving average of the roll signal over 5 minutes. This results in a low pass filtered time series as shown in Fig. 4. This time series can easily be checked against the criteria.
In any case, in the tests we have carried out, the model either catastrophically capsized or was far from the given limits. We never found a doubtful situation.

5 TRANSIENT FLOODING TESTS

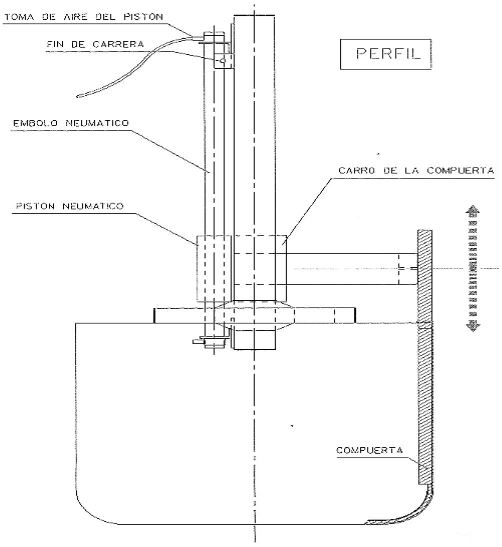

Figure 5. Damage opening device

Many passenger ships have longitudinal bulkheads at distances larger than B/5 from the ship side (so not affected by the IMO standard damage) in order to comply with the requirements for damaged stability. This will result on a asymmetric flooding with the corresponding heel. To minimize or eliminate this heel, means have to be provided for up righting the ship, means that should be preferably automatic.

One simple way to accomplish this is to connect the affected space with a symmetric one by means of , permanently opened, cross ducts trough the double bottom. This ducts have to be designed in such a way that the transient heel never exceeds 20º during the cross flooding phase and such that the cross flooding is achieved in less than 15 minutes.

Numerical codes have are being developed in order to predict this kind of behaviour in the project phase. These codes need experimental data for its validation and tuning.

To this purpose an extensive set of tests has been carried out at the seakeeping basin of CEHIPAR.

For these tests a model of a damaged ferry vessel similar to those described in the previous section was used. The damaged was initially closed with a fibreglass cover with the shape of the damage hole and the ship stayed in an upright position with all the compartments dry. Water tightness was insured by means of aluminium adhesive tape. The cover was kept in position by a vertical pneumatic cylinder (see Fig. 5).

The test started by actuating the pneumatic cylinder moving the cover vertically up in a quick way. The water suddenly begins to flood the damage spaces producing a quick heel towards the damage. More slowly the cross flooding occurs compensating the heel until, eventually, the model is again in an upright position.

During the test, both the instantaneous heel and the water elevation in some points inside the flooded compartments is recorded.

The tests were repeated for several GM's and different configurations of the cross ducts connecting the symmetric flooded spaces.

In this kind of tests, the correct reproduction of the internal configuration of the flooded spaces, their permeabilities and vent effects is even more important than in the previous kind of tests.

Similarly to the case of the vents, special care has to be put in avoiding scale effects due to viscosity in the resistance of the cross ducts to water flow. So that, if they are too small, their size should be increased adequately to get realistic effects.

The opening device should be light to reduce inertia effects and appreciable changes in the GM. In our case we observed that the action of this device produced a heel of less than 0.2º.

In order to precisely changing the GM without affecting the transversal inertia, some ballast weights were put on worm drives manually actuated.

6 SEAKEEPING, SURVIVAL AND SLOSHING TESTS WITH REDUCED DEGREES OF FREEDOM

When doing tests to get insight into the physical phenomena behind the behaviour of the ship in waves or for code validation purposes, it is sometimes interesting to simplify the tests so that the coupled influence of different parameters can be isolated and the results can be more easily analysed.

One possible way to do this is to reduce the number of degrees of freedom of the problem at hand.

This can be done, for example, by converting the original 3D problem into a 2D one and this can be achieved at least in two ways. One is to reproduce a prismatic section of a tank or compartment, flood it with water and oscillate it in a prescribed manner recording the flow inside the tank and if necessary the forces and moments generated by the fluid either globally or locally. This is done out of any ship model and could be called sloshing tests.

A second alternative is to use a prismatic model located transversally in a narrow tank with some guide system to avoid friction of the model against the walls. In this case care has to be taken to avoid that the waves reflected from the model back to the generator return to the testing area. Therefore the test has to be short enough or the wave maker has to have active adsorption capacity.

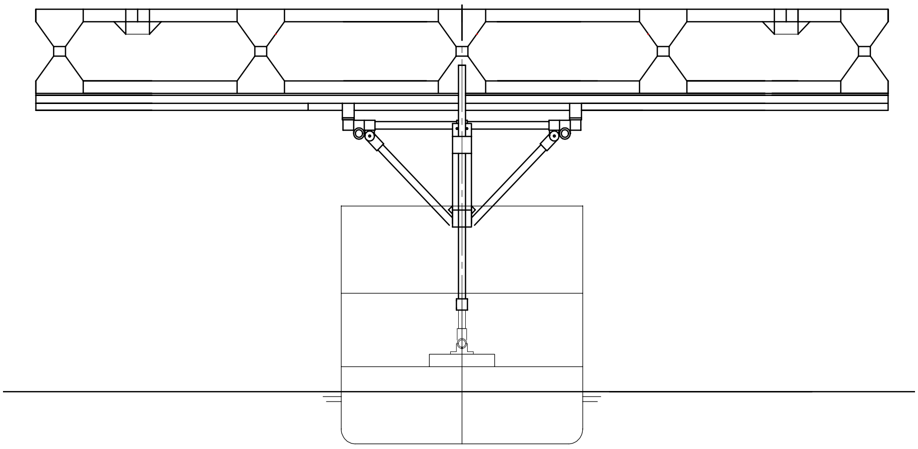

Figure 6. Sketch of sub-carriage

Alternatively, instead of reducing the number of dimensions, one can keep the problem as 3D by using a conventional model of the ship but restrain one or more degrees of freedom of is motions as desired.

For the kind of problems considered here, it is normally the yaw and pitch motions the ones that are required to be restrained. To this purpose we have designed and built a device working as a sub-carriage behind the main carriage. This small sub-carriage runs along two linear guides attached to lower part of the CPMC. It carries itself linear bearings along which two rods can run vertically with small friction.

This system restrains the model from yawing. Other degrees of freedom can be restrained depending on the configuration. Heave can be avoided by fixing the vertical rods by means of brackets. If the vertical rods are clamped to the model, roll and pitch are eliminated. If this connection is made through bearings with a longitudinal axis of rotation, roll is allowed. If, instead, two ball joints are used, both roll and pitch are permitted (one of the joints has to have a double articulation to compensate the relative longitudinal displacement of one attachment point to the other when pitching). Of course, sway can also be restrained by braking the carriage.

This small carriage introduces an additional inertia for the sway motions, i.e. the mass in the sway direction is somewhat larger than from the other motions. This can be taken into account in the computer programs, but in any case, at CEHIPAR it has been constructed with an aluminium pipe lattice whose weight is around 18 kg for a typical model displacement of 600 kg and therefore the increase in mass is only 3%.

This system allows also the simulation of the additional drift produced by the wind and currents. This can be done by adding a constant towing force to the sub-carriage or by restraining it with soft springs an towing it at a constant mean speed.

7. FORCED EXCITATION TESTS

Forced excitation tests have been used for years to obtain benchmark data for validation of seakeeping computer codes. These tests can consist in oscillating the model in one degree of freedom and measure the forces necessary to produce these motions from which added masses or inertias and damping are obtained. This contribution is known as radiation forces.

Alternatively, the model can be fixed in the middle of a regular wave field. Forces measured on the model are the so-called diffraction forces.

Here, we consider these kind of tests in the context of evacuation research an then the important parameter is not the forces involved but the water motion produced around the ship by these diffracted and/or radiated waves.

This water motion can be used for comparison with predictions from computer codes or used as input to calculate the seakeeping behaviour of evacuation devices like lifeboats.

For forced oscillation tests in evacuation studies, the interesting motions are heave, roll and sway. For the sway oscillations the CPMC capabilities are used to move the model transversally in a sinusoidal motion. For heave and roll oscillations an especial vertical oscillator is used which by means of two electrically actuated cylinders acting in or out of phase will generate the desired motions.

The wave elevation around the model can be measured at several points by means of wave probes.

The motions observed in the windward side are those corresponding to an almost stationary wave made up from the incoming wave and the wave reflected on the ship's side. Its elevation is very much amplified near amidships and goes down to the ends. At the leeward side a very calm area is observed.

8. TESTS OF EVACUATION SYSTEMS

The last kind of tests we are going to consider here are those regarding the behaviour of conventional or novel evacuation systems. As stated before, our collaboration with Chalmers University of Technology, fully financed by the EU, has gave us the opportunity to gain experience in the testing of evacuation devices.

These tests are especially challenging because of the large difference in size between what we will call "mother ship" (the ship being abandoned) and the evacuation systems.

Figure 7. The mother ship and one life boat

After a close collaboration between both institutions we think we have being able to carry out a set of tests which can give a good insight on how the evacuation systems behave during release and near the mother ship. We hope, the data obtained can be useful in improving the way evacuation from damaged ships can be done.

Two ways of evacuating passengers, with different requirements for testing, have being considered: the lowering of people in boats with a mechanical davit and the active evacuation of people trough flexible chutes to a floating landing platform. They are described in more detail in the following.

8.1 Life boats lowered by davits

We used for these tests a model similar to the previous ones but in the intact condition. The different aspects of the tests are considered in the following.

The davit model

The davit was simulated by two pulleys moved by a computer controlled step motor. The position of the davit could be changed in height and in separation to the hull side in order to investigate the influence of these parameters. The computer program controlling the davit allowed regulating the speed and acceleration of the descent of the lifeboat. We tested several variations of constant speed or constant acceleration.

Another important parameter for this kind of evacuation devices is the moment at which it is released. It the release takes place before the boat reaches the water, it can be dangerous unless the boat is designed for this kind of water entrance. If made too late, the mother ship can, in a violent roll motion, pull the boat catastrophically towards the shipside or made it capsize.

To simulate this action, the attachment of the davit hoisting lines to the boat was made trough electro magnets that could be activated by the same computer program controlling the davit lowering motion. The release moment could be previously established or forced manually to observe extreme situations like the case in which the hook release is delayed and the boat remains dangerously tied to the ship .

Figure 8. Lifeboat and life raft models

The lifeboat models

The main difficulty was to fabricate the models of the lifeboats as, for the scale chosen of 1:30, they had a displacement of around 0.5 kg, including the instrumentation and some ballast to adjust the centre of gravity. Therefore, the boats were made in divinycell foam covered by a thin film of FRP.

Due to this small size, we did not attempt to reproduce such weight distribution characteristics as the inertia because it will be almost impossible. Therefore, we limited ourselves to reproduce the total mass and the natural roll period as determined from full size lifeboat tests.

Two different lifeboat models were built for this kind of tests. One of them was a conventional lifeboat. The other was an special design known as “fall boat”. The hull forms were equal to the conventional one, except for a wedged bottom intended to reduce the impact forces and accelerations produced when released before reaching the water or lowered with higher speeds or accelerations than for a typical boat.

The instrumentation

If making a model of such size is difficult, trying to measure anything on it is a challenging task. The physical magnitudes of interest are the 6 degrees of freedom motions of both the mother ship and the boat and the accelerations in three orthogonal axes.

The motions were measured by the same optical tracking system as for the mother ship as it allows the simultaneous tracking of two objects by installing three calibrated diodes on each one.

The accelerations were measured by three accelerometers in the centre of gravity of the boat in three perpendicular directions. The accelerometers need to have a very high (more than 1 kHz) frequency response in order to capture acceleration peaks produced by the entrance in the water or by crashes against the hull side.

Figure 9. The chute and the life raft models

Clearly, the accelerations produced by the hull side depend on the stiffness of the boat and the hull itself. We did not try to reproduce such stiffness But we needed a way to extrapolate the results to the full scale case. To this purpose we used data from a drop tests on real ship. This tests consists in hanging the boat at a certain distance down the davit, separating it from hull a known distance and releasing it to produce a crash against the mother ship while measuring the transversal acceleration. We repeated this tests in the models in order to get two values (full scale and model scale) that could serve as a comparison. By chance, we got almost the same accelerations in both cases.

8.2 The chute system

The chute system consists in a vertical flexible tube hanging from a deck of the mother ship. The tube dimensions and construction is such that the falling speed of people descending through it is controlled. The bottom end is attached to a landing platform moored to the ship side. This platform is similar an inflatable life raft. People landing on the platform will be collected by life rafts moored to it.

The chute and life raft models

The chute was simulated by means of plastic cloth reinforced by plastic rings at equal intervals.

The landing platform and rafts were made of foam cylinders with a porous plastic bottom. A varying amount of small ballast was added to simulate the presence of different numbers of people. For more realism, the life rafts were fitted with a canopie.

Instrumentation

The main interest of the tests for this kind of evacuation system is to measure the distance between the disembarkation point in the upper deck and the landing platform. This is because, if this distance exceed the elongated length the chute, the landing platform will be pulled up and the staying people can be thrown overboard. On the contrary, if the chute becomes too slack, it will bend in a “J” shape and people descending though it will be trapped in the bend and even immersed into the water.

To measure this distance, the landing platform has been fitted with diodes as done for the life boats tests. This allows the simultaneous recording of the ship and platform motions from which the distance of interest can be calculated.

9. REFERENCES

[1] Stockholm Agreement SLF 40/Inf in accordance with SOLAS 1995 Conference Resolution 14.

[2] "Interim Guidance Notes for a Uniform Model Test Procedure" draft 3/14.596, English Administration.

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