

SESSION 2a

ON STABILITY TESTING AND CORRELATION

Discussion Chairman: Prof. O. Krappinger

Recorder: Dr. O. Rutgersson

2a-1. Introduction of the Subject

O. KRAPPINGER - Hamburg Ship Model Basin, Hamburg, Federal Republic of Germany.

CHAIRMAN'S INTRODUCTION

At the Second International Conference on Stability of Ships and Ocean Vehicles 1982 in Tokyo (Stability '82 [2]) a wealth of valuable papers was presented. They are rewarding from a scientific point of view, but nevertheless the potential users of the papers (i e naval architects or administrators being responsible for the safety of new ship designs) feel a bit left in the church. Indeed they did not get much ready-for-use advice. On the contrary, the abundance of ideas and proposals (which provide a nice playing field for theoreticians) is rather confusing to them. In this respect the situation did not improve since the First International Conference on Stability of Ships and Ocean Vehicles 1975 in Glasgow [1]: The theoretical playing field has been extended and the position of the users

has scarcely been ameliorated. Somehow it appears that the naval architectural profession has become deadlocked with respect to the problem of safety against capsizing.

In this situation it might be useful to find out how in other fields problems of similar complexity have been solved. As an example I will consider the powering of ships. Let us forget for the moment all we know about the present methods for predicting the power which is necessary that a given hull obtains a required speed. One has to think a little bit about what this means: It implies that we are ignorant of the ingenious ideas of Froude and do not have the experience of more than hundred years of tankery.

If in this situation we would approach the powering problem in a comparable way as we handle the stability problem we would have on the one hand a simple formula (i e the Admiralty Formula) which widely neglects the physical facts involved and is mainly based on experience. This powering method corresponds to providing safety against capsizing

by the Rahola method.

On the other hand we would have many sophisticated theories which try to take care of the involved physical facts (as wave making, viscous effects etc) but are of little use for practical purposes. This corresponds to the efforts to solve the capsizing problem by theoretical investigations of the dynamic behaviour of ships in waves.

Maybe that in the situation considered here the impossibility to satisfy all relevant scaling laws would have prevented us to resort to experiments. But thanks to Froude tank testing has become a powerful tool for solving many problems connected with ship powering. One wonders why with regard to ship stability the experimental approach hitherto has been widely neglected.

Of course I am aware of the capsizing tests which have been made in the past at several places all over the world. I also agree that we got a lot of information on the mechanism of capsizing from these tests. But they can be scarcely considered as a generally accepted tool for the prediction of stability requirements for particular ships in given environments.

In order to introduce capsizing tests on a similar level as e g manoeuvring tests standard test procedures would have to be developed and agreed upon. It is one of the purposes of this Group Discussion to find out if and in case which ITTC Member Organisations are interested to participate in the development of standard procedures for capsizing tests.

References

- [1] International Conference on Stability of Ships and Ocean Vehicles, University of Strathclyde, Glasgow, March 1975, Proceedings, Glasgow 1975 (382 p.)
- [2] International Conference on Stability of Ships and Ocean Vehicles (Stability '82), The Society of Naval Architects of Japan, Tokyo October 1982, Proceedings, Tokyo 1983 (800 p.)

2a-2. Invited Contributions

Following his Introduction of the Subject the Chairman introduced the authors of the four Invited Contributions, given below.

A. MORRALL - NMI Ltd, Feltham, United Kingdom.

STANDARD PROCEDURES FOR CAPSIZING TESTS

(Presented by S. Rowe, NMI Ltd)

It is suggested that a framework for conducting model "capsizing" tests could be developed on a pragmatic basis. If it is understood from the beginning that the results of such tests would not be absolute, but would nevertheless provide useful design guidance, then such tests are worth considering. The results of these tests are unlikely to be very sophisticated and the degree of success or failure in the first instance will depend crucially on the appropriate choice of wave spectra or design wave parameters. Ultimately,

the results will need to be validated or calibrated against existing stability criteria, such as IMO Resolution A.167.

Model experiments are unlikely to provide the full answer to the stability problem since experiments can only be carried out in a relatively limited range of conditions, and it is necessary to extrapolate the results to cover a vessel's lifetime of loading and operating conditions; this is precisely where a theoretical model is needed. There are also problems with model experiments concerning scale effects.

In the present context there are many possible types of capsize situations that could be considered. However, it is generally accepted that for merchant vessels the greatest danger from extreme roll motion leading to capsize is from following or quartering seas. Extreme rolling can of course take place in beam seas although there is little evidence that this results in capsizing in practice, except when water is shipped and retained on deck. It is also widely recognised that steep pyramidal waves formed in crossing sea conditions can be especially hazardous, particularly for fishing vessels.

The aim must be to provide test conditions which offer realistic descriptions of the environment likely to be encountered in service. Moreover, it is important to provide data from which realistic descriptions of wave histories as well as estimates of extreme events and their probabilities of occurrence can be derived. The capability for modelling realistic wave histories, which include valid representation of grouping properties such as sequences of high

waves, is particularly important because rolling responses can be highly non-linear and hence very sensitive to such effects.

It is difficult to generalise model tests into rational stability criteria which are applicable to whole classes of vessels, although such data would be valuable for evaluating existing criteria. A primary problem in establishing stability criteria is the sensitivity of dynamic behaviour, to capsize in particular, and to details of vessel geometry. Model tests may not adequately predict capsize because of the absence of realistic environmental conditions or due to scale effects, but they do offer the opportunity of obtaining selected data for assessing safety against capsizing of the model. It will be necessary to carry out a sufficient number of repeat tests to give an adequate exposure time to the wave conditions and this should correspond to at least one hour at full-scale. Once validated with existing stability criteria or full-size data then statements can be made about the safety of the vessel.

S. MOTORA - Nagasaki Institute of Applied Science, Nagasaki, Japan.

SOME PROBLEMS CONCERNING STANDARDIZATION OF CAPSIZING TESTS

I would like to raise few points concerning standardization of "capsizing tests".

1. Scaling Problems

The law of similarity for hydrodynamic force and moment acting on a rolling or capsizing ship are very much complicated.

It can be said that the restoring moment and wave induced force and moment almost follow to the Froude's law of similarity. On the other hand, frictional and eddy making damping are strongly related to the Reynolds number.

Since measured ship motion in capsizing test is the result of such complicated hydrodynamic force, it may not be practical to scale up the measured motion of a model to the full scale ship dividing ship motion into two parts; one following to the Froude's law of similarity and the other following to the Reynold's law of similarity.

Therefore, it will be more practical to adjust the hydrodynamic force and moment of the model to be similar to the full scale ship.

Restoring moment, added mass and added moment of inertia, and wave induced force and moment: since these force and moments are mainly induced by potential flow, they follow Froude's law of similarity. Therefore no correction or adjustment will be necessary.

Damping force and moment: though the wave making damping follows the Froude's law of similarity, frictional and eddy making damping, which is the major part of the damping, follow the Reynolds law of similarity. Thus, the damping of a model is larger than the corresponding full scale ship and therefore, usually, a model tends to be more difficult to capsize than the full scale ship. Consequently, it will be necessary to reduce the damping of a model to some extent. The followings are some examples of practical methods:

Reduced size of bilgekeels: it may be

possible to reduce the damping by reducing the size (width) of bilgekeels. It is of course an approximate method because wavemaking damping needs not be adjusted. Extent of reducing bilgekeels should be studied by model - full scale comparison.

Adding negative damping by a computer controlled torque generator.

Size of freeing ports on bulwarks: since the effect of shipping water on deck will be affected by the size of freeing ports, it will be necessary to adjust the size of freeing ports (freeing ports for a model being larger than full scale size).

2. Standard for Waves

It is of course necessary to set-up a set of standard waves for capsizing tests.

For such standard waves not only specifying wave spectra but specifying standard time series of specified length may be useful for comparison.

3. Standard for Wind

In choosing standard wind, distribution of wind speed as function of distance from sea surface and the spectrum should be specified. A simplified series of gust wind may be also useful in testing and analysis.

R. K. BURCHER - Admiralty Research Establishment, Haslar, Hants, United Kingdom.

STABILITY TESTING

1. The purpose of investigation into ship capsize is to avoid the catastrophe of a vessel lost. It is thus different to the more usual role of tank testing to predict the performance of a vessel. If it were possible to produce a criterion based on simple assumptions which would guarantee a vessel against capsize then it might well be adopted, especially if it did not entail any operational penalties. Unfortunately no such criterion has been established; those that do exist have not prevented losses.

2. Mathematical Models: To undertake model test investigations into capsize it is necessary to have some form of conceptual or mathematical model so that the tests can be devised and interpreted. This is what Froude did most successfully for resistance by proposing a relatively simple hypothesis which, though not entirely correct, has stood the test of time.

3. We are currently faced with a variety of theoretical analyses of capsize which are not all readily comprehended by designers and regulating authorities. Many are couched in mathematical terminology (Eigenvectors, Lyapunov functions) which deny explanation in physical terms.

4. Modelling Sea Conditions

(a) Wave spectra - As a means of determining the distribution of total responses and hence the probability of exceeding some moderate heel angle it

is a very appropriate tool. However when considering extreme and hopefully rare events such as capsize its value is doubtful in that the spectrally correct waves generated may not contain the sequence that could give rise to the problem.

(b) Regular Waves - Testing in regular waves and relating this to real seas relies on the linear superposition assumption that is unlikely to hold in large rolling motion. On the other hand resonant responses may well be associated with a narrow frequency band in which case regular wave testing may well be a means of identifying potentially dangerous response.

(c) Time Sequences - Multi degree of freedom, non linear systems may well experience the worst response due to a particular time sequence of inputs. Without any prior knowledge or sound mathematical model it is difficult to be sure by tank testing that such a sequence has been covered. If the response is narrow banded then regular wave testing may give guidance or a hint of potential problems and it is possible that further tank testing in this narrow band will discover the particular sequence by methodical variation of phase and frequency. If the response is wider banded it may be possible to use spectral testing to identify particular sequences with cause greater response. These observations might then be used as feed back to reinforce the spectra in this area and hopefully "home in" on particular sequences which give rise to problems.

5. Types of Testing

(a) Free running models - this is the nearest approach to reproducing conditions at sea in a real ship. However some care needs to be taken regarding scaling; damping effects, which may well be critical in resonant phenomena, will probably not scale correctly. It may be necessary therefore to consider non-geometric similitude of appendages, particularly bilgekeels, in order that the model predicts full scale behaviour.

(b) Partially constrained models - A number of tests have been conducted on simple hull shells held at some attitude to the waves by mooring wires. This is probably the simplest and cheapest way of observing response and capsize in waves. However it does raise the question as to whether the restraints introduce forces, however small, into the system that contribute to the capsize or whether the restraint of yaw, sway and surge alter the response characteristics of the system.

(c) Fully constrained models - This is the equivalent of that used in manoeuvring work in that the object is to measure the forces and moments on a hull due to wave action or to imposed motion of the hull in waves. Again it is seen as predominantly a research tool to evaluate the force/motion relationship so that the mathematical models can be evaluated and "real" values of coefficients introduced into the analysis.

G. van OORTMERSSEN - Maritime Research Institute Netherlands, Wageningen, The Netherlands.

ON THE ASSESSMENT OF STABILITY

The assessment of the stability, or maybe it is better to say safety against capsizing, of ships and floating structures is a very difficult problem.

The current practice is based on static considerations, and usually no environmental loads other than steady wind are taken into account. A certain margin is built-in in the criteria, to account for dynamic effects.

The present rules are mainly based on a statistical analysis of past casualties, which means that they are only adequate for conventional ships, for which a long experience exists.

The intact stability criteria in use for floating offshore structures like semi-submersibles are empirical and similar to those developed for ship-shaped vessels. The limited applicability and consequent need for more meaningful, rational criteria which take proper account of the dynamic nature of platform motions is widely recognized.

The tools we have available to investigate stability and capsizing are limited.

On the analytical side, we can use equations of motion to calcu-

late motion response in extreme conditions in the time or frequency domain, or, alternatively, determine the stability of the equations by means of the Routh criterion or Lyapunov's direct method.

We should, however, keep in mind that the equations of motion we have at present to our disposal, are not adequate for describing large motions, let alone capsizing and there are uncertainties in the coefficients in the equations, in particular the damping coefficients. Moreover, the mathematical problems involved in using a direct method are extremely difficult so solve. Model testing seems a more appropriate tool, but we have to consider possible scale effects which may affect the roll damping, which is a crucial factor in instability phenomena. A problem in both analytical work and tank testing is a correct modelling of the wind effects, which are extremely important for platform behaviour. The solution for this problem seems to be wind tunnel testing at the correct Reynolds scaling, but then we face the fact the shape of the waves and their position relative to the platform appear to have an important influence on the wind heeling moment, and waves can not be modelled in a wind tunnel, at least not in a dynamic way.

In addition, testing in steady wind may be too restrictive. As shown in a recent study at NMI (1) low frequency motions may be induced by a realistic wind of varying velocity.

When damage or system failures are considered, the problems become

even greater. Large heel angles and internal free water surfaces introduce additional non-linearities (see ref. (2)). Also, the number of conditions to be considered increases tremendously. A capsizing is often the final result of a chain of events which may have started with a minor incident. Many scenarios should be imagined in order to determine the critical situations to be investigated.

We should beware of becoming discouraged by this list of problems and shortcomings of our present tools and understanding. To the contrary, I think we should face the challenge and increase our efforts in developing methods to assess the stability of ships and floating platforms which will eventually lead to safer designs. In this respect I think what we need most is a conceptual scheme, which tells us how we can use our limited tools to approach the stability problem in a rational way.

At the same time, we should improve our tools, both the analytical and experimental, in order to increase their applicability and accuracy.

References

- [1] Rowe, S.J., Brendling, W.J. and Davies, M.E. "Dynamic wind loading of semi-submersibles", RINA Symp. on Developments in Floating Production Systems, London, March 1984.
- [2] Huang, X. and Naero, A. "Dynamic response of a heavily listed semi-submersible platform", Proc. 2nd Int. Symp. on Ocean Engineering and Ship Handling, SSPA Göteborg, March 1983.

2a-3. Additional Prepared Contribution

The Chairman offered the floor to Prof. Kobylinski for an additional Contribution.

L. KOBYLINSKI - Ship Research Institute, Technical University Gdansk, Gdansk, Poland.

CONTRIBUTION ON STABILITY TESTING

Model tests are a useful tool for assessing of safety of ships against capsizing providing one is fully aware of all possibilities and limitations of such tests. Therefore the idea of preparation of a Code of Model Testing of Stability should be supported.

Model tests of overall safety against capsizing are probably the most complicated of all model tests in view of the necessity of observing the following factors:

1^o the realistic simulation of all changing environmental conditions

2^o the simulation of the above-water shape of the ship including openings in superstructure, bulwarks, freeing ports, etc

3^o scale effect with regard to the flow through narrow passages (freeing ports!) and around bilgekeels etc

4^o simulation of the action of the helmsman (human factor!)

5^o running model in waves over considerable period of time in order to obtain hundreds of wave encounters (capsizing is a rare event!)

6^o no practical possibility to obtain model-full scale correlation (even if capsizing of a full scale ship is modelled, exact conditions and sea state at the time and place of capsizing are never known!)

Because of the difficulty of conducting of model tests of the overall safety against capsizing, various partial model tests are performed, each of them giving some useful information with regard to safety against capsizing. Such tests might be listed as follows (and they probably might constitute the scope of the future Code):

A. Model tests of ship characteristics affecting safety against capsizing:

1. Static heeling test (small and large angles of heel)
2. Loss of stability in wave crest; stationary wave
3. Rolling behaviour in still water
4. Rolling behaviour in beam seas
5. Rolling behaviour in following waves
6. Broaching to phenomenon
7. Wind tests

(The list is not complete - might be expanded)

B. Model tests of the overall safety against capsizing in natural environment (simulated or real) - various heading against wind and sea.

Obviously, considerable amount of work is required in order to prepare such a Code.

2a-4. Free Discussion

The Chairman opened the discussion by dividing the problem into three parts. The first question was "What seaway to be used in capsizing tests?".

Dr. Burcher had the opinion that regular waves should be preferred as they are more well defined than irregular waves. *Dr. Rowe* did not agree, and *the Chairman* suggested that the question was closely related to that on what results are looked for. (See below)

The second question was concerned with Scale Effects. *The Chairman* first showed some results from tests with four different models in the Hamburg Model Basin. He also stated that water-on-deck seldom seems to be a problem, but that it would be good if the Seakeeping Committee would consider this question.

Dr. Burcher gave an example where a small change in damping had made capsizing to occur after the passage of six waves instead of after two waves only in the original setup.

Prof. Kobylinski had the experience that the wave grouping of 3-4 nearly regular waves often causes the capsizing. He therefore believed that regular waves could be used for these kind of tests.

Mr. Murdey mentioned that capsizing

tests put some strain on wavemaker capabilities as high and steep waves are required.

The third question to be discussed was "What information can be expected from capsizing tests?".

The Chairman opened the discussion by saying that people often claim their reason for not carrying out capsizing tests to be that "they have nothing to measure" in such tests.

Again he presented some relevant results, which were to be published at the Meeting of the Schiffbau-technische Gesellschaft later in 1984. Upon a question by *Dr. Price* the Chairman replied that the displacement was an important parameter in the results obtained.

Prof. Schmiechen asked the Chairman how often he had to repeat the tests, to which he replied that if capsizing did not occur after 5 runs the test conditions were made worse; if capsizing did still not occur after a total of 15 runs, then use was made of the earlier explained method. The Chairman also declared that he is confident with the methods used in Hamburg and would invite also other ITTC Member Organizations to carry out such tests.

Dr. Price referred to some measurements carried out in British tanks.

Finally a lively discussion took place between *the Chairman*, *Prof. Abkowitz*, *Dr. Price* and *Dr. Rowe* regarding the way to model the random sea in scale model tests.