AN EXPERIMENTAL INVESTIGATION IN THE FRAMEWORK OF THE ALTERNATIVE ASSESSMENT FOR THE IMO WEATHER CRITERION

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This paper presents a summary of the outcomes from a series of experimental tests (zero speed roll decays, rolling in beam waves, lateral drifting in calm water) on three GEOSIM models. Experiments have been carried out and discussed in the framework of the alternative experimental assessment of the Weather criterion as allowed by the recent IMO MSC.1/Circ.1200.

1. INTRODUCTION

The International Maritime Organization (IMO) has recently issued the MSC.1/Circ.1200 - "Interim Guidelines for the Alternative Assessment of the Weather Criterion" (IMO, 2006), which contains guidelines for conducting experiments aimed at determining, on an experimental basis, the following relevant parameters for the assessment of the "Severe wind and rolling criterion (weather criterion)":

- The wind heeling moments through wind tunnel tests;
- The moment due to the hydrodynamic reaction during steady lateral drift;
- The angle of roll due to the action of waves.

The availability of an experimental alternative to the statutory rules represents a potential for the optimization of the design of a ship according to her real(istic) performances at sea. However a very limited experience is presently available on the application of MSC.1/Circ.1200. The experimental campaign summarised in this paper aimed at investigating some aspects of the experimental approach proposed in MSC.1/Circ.1200 and in particular the possible presence of scale effects on roll damping estimated from roll decays as well as on roll motion in beam waves, and the characteristics of hydrodynamic reaction in steady lateral drift motion. To investigate such aspects, experiments (free roll decays, roll tests in regular beam waves and drift tests) have been carried out using three GEOSIM models (scales 1:33, 1:50 and 1:65) at "Canal de Experiencias Hidrodinámicas de El Pardo (CEHIPAR)". This paper reports a very brief summary of the outcomes, with the exception of results from drift tests which, due to some experimental ambiguities, did not allow to reach definite conclusions. An extensive analysis can be found in Bulian et al. (2009).

2. HULL FORM

The hull form used in this study is the CEHIPAR2792, provided by CEHIPAR. The CEHIPAR2792 does not correspond to any real ship and it was built for the purpose of this research. A 3D view of the hull form is available in Figure 1 and main particulars are given in Table 1.

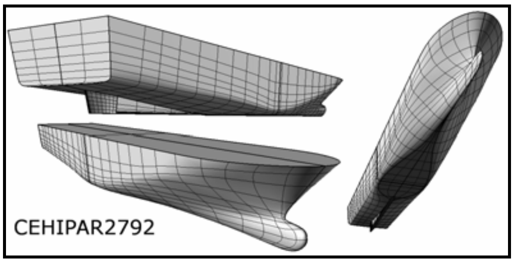

Figure 1: CEHIPAR2792. 3D view.

Table 1: Ship main particulars

Reference Length	[m]	205.7
Depth	[m]	20.2
Breadth overall	[m]	32.00
Volume @T=6.6m	[m^3]	23986
C_B @T=6.6m	[nd]	0.587
KB @T=6.6m	[m]	3.794
BM_T @T=6.6m	[m]	14.064

The ship was tested in bare hull condition and with bilge keels, with the projected surface of bilge keels corresponding to 1.3% of the product $L \cdot B$.

3. ROLL DECAYS

The ship roll degree of freedom is likely to be the most important when safety is of concern in intact condition. At the same time a correct estimation of roll damping is of key importance for a correct estimation of rolling motion in waves. It is therefore clear that the knowledge of ship roll damping plays a fundamental role in the estimation of ship safety against capsize, because when strong roll dynamics is to be avoided, an efficient energy dissipation through damping is necessary. At zero speed, i.e. in the case relevant to the scenario addressed by the Weather Criterion, roll damping is mainly due to skin friction, vortex shedding and wave radiation. It is presently not clear, however, whether scale effects could play a significant role in full scale damping estimation from model tests.

In the best authors' knowledge, a sufficiently large family of GEOSIM models has never been tested with the scope of addressing roll damping scale effects, or at least, has never been made public. Some experimentation on this aspect is nevertheless available (see, e.g., Valle et al. (2000) ; Bertaglia et al. (2004)) but considerations on the existence and possible magnitude of scale effects on roll damping has mostly been based on theoretical / semi-empirical calculations (e.g. IMO (2006) ; Vossers (1962)). According to these premises and taking into account that roll damping is one of the relevant parameters in the experimental assessment of the Weather Criterion (IMO 2006, 2007), part of this research addressed the analysis of experimentally obtained roll decays. Roll decay tests have been carried out for the three model scales with two different metacentric heights (2m and 4m full scale) with and without bilge keels. A total of 60 roll decays have been performed. In order to increase repeatability, to reduce the influence of parasitic vertical forces, and due to the large required inclining moments, in particular in the case of largest model, the initial inclination was given using the setup shown in Figure 2.

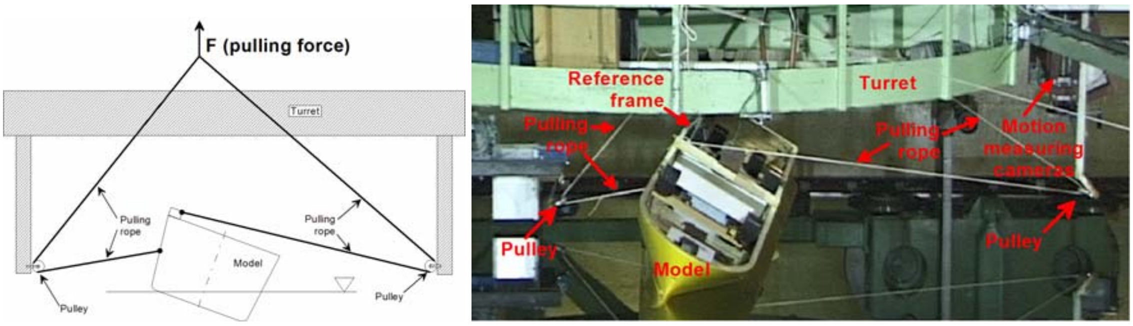

Figure 2: Schematic diagram (left) and actual realization (right) of the experimental arrangement used for roll decay tests.

In order to aggregate data from different roll decays the processing of data was based on the analysis of roll decrement curve. A typical comparison between tests at different scales is shown in Figure 3 where the full-scale equivalent linear damping coefficient is shown as a function of the rolling amplitude.

From the experiments and the subsequent analysis it was not possible to identify a clear trend that could be associated to scale effects, although some indications have been found of a possible reduction of the linear roll damping coefficient as the model dimensions increase (and this was expectable). The variation of roll damping associated to scale effects, however, is likely masked by the global uncertainty involved in this type of experiments. Indeed, the execution of the experiments proved to be more complex than expectable especially for large models. The global level of uncertainty is due to components associated to the building of models; to the construction and fitting of bilge keels; to the ballasting of the model and setting up of the metacentric height and roll period; to the measuring of motions; to the methodology of analysis of the obtained data; to scale effects. In addition part of the global epistemic uncertainty is to be ascribed to the "mathematical model uncertainty". The problem of extrapolation of damping models to rolling amplitudes significantly larger than the maximum rolling amplitude used in roll decay experiments has also been addressed, especially in bare hull condition: since the wave steepness required by the Weather Criterion is quite large, it is not uncommon that the final rolling amplitude in the reference wave condition is outside the range of amplitude available from roll decays. The damping correction as reported by MSC.1/Circ.1200 has been applied, giving quite fuzzy results: a definite conclusion on its suitability cannot be drawn but some of the hypotheses on which such correction is based have been criticised.

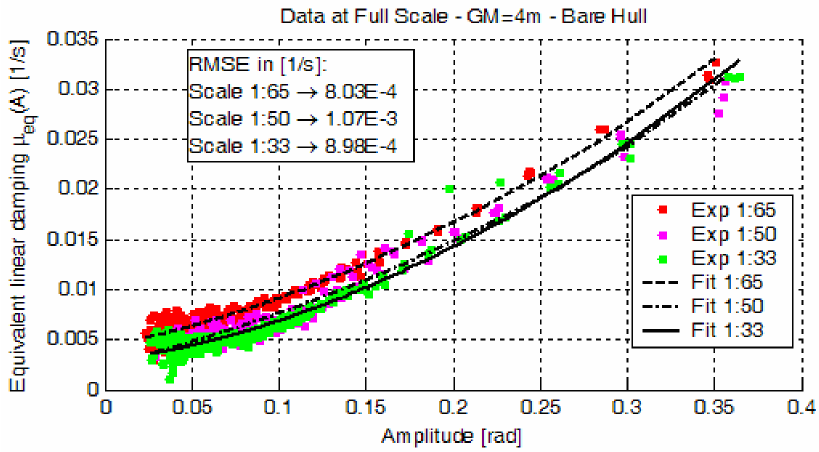

Figure 3: Analysis of decays. GM=4m, bare hull condition. All scales.

4. ROLL TESTS IN BEAM WAVES

Roll tests in beam waves are an important part of the experimental assessment of Weather Criterion according to MSC.1/Circ.1200. In the present experimental campaign it was not possible to generate waves as steep as required by the Weather Criterion for all model scales, due to limitations in the wave generation system. In particular, while waves with high steepness (ratio wave height over wave length) can be generated for relatively small models, the same is not possible for large models. This is due to the long waves involved, especially if the roll natural period of the ship is large. Such limitations are common to the majority of experimental facilities around the world, and this poses some concerns on the actual applicability of the direct assessment methodology in MSC.1/Circ.1200 for large scale models (as it would be desirable to avoid the problem of scale effects). For the loading condition associated to GM=2m (full scale), tests were carried out for all the model scales with a wave steepness of 1/80. For the loading condition associated to GM=4m (full scale), tests were carried out for two wave steepnesses, namely 1/80 and 1/40. For sake of comparison, the Weather Criterion, for this ship, would require a steepness of about 1/17 for GM=4m and 1/27 for GM=2m. The model was free to drift and manually controlled (with some difficulties in case of large models) to avoid too large heading deviations, as specified in MSC.1/Circ.1200. Generated waves were analysed and tests not conforming quality requirements were discarded in the subsequent analysis. The analysis of generated waves pointed out the necessity of considering the effect of limited tank's depth in this type of tests due to the length of the involved waves when models are large. Two mathematical models have been employed for the prediction of roll motion, based respectively on a 1-DOF time domain nonlinear approach (roll) and a 3-DOF frequency domain nonlinear approach (roll-sway-yaw). Nonlinearities have been considered in roll damping (with coefficients from experiments) and restoring. Two examples of comparison between experiments and numerical predictions are shown in Figure 4.

Roll amplitude prediction has also been carried out using the methodology in the present Weather Criterion. From the obtained results it was possible to arrive at a series of observations. First of all, similarly to the case of roll decays, the obtained roll response curves did not show any clear trend that could be associated to scale effects. It is however not possible, at this stage, to generalise the obtained result for different hull forms. Concerning the behaviour of the roll response curve, in none of the tested cases the peak of the response curve was found at an encounter frequency equal to the roll natural frequency, due to nonlinearities in the roll restoring: performing tests only at an encounter frequency equal to the roll natural frequency is thus likely to lead to severe underestimations of the roll motion, especially in case of low metacentric heights. The suitability of the basic Weather Criterion formula to predict the roll amplitude in beam regular waves has been assessed, by substituting the statutory steepness with the experimental ones. The measured rolling angle was usually underestimated by the Weather Criterion formula when the skeg is considered in the computation of the roll reduction factor, and better overall performances are obtained omitting the skeg area from the calculation. It was also found that the Weather Criterion underestimates the efficiency of bilge keels in reducing the amplitude of roll peak. Very good performances of the employed mathematical models have been obtained in case of ship models fitted with bilge keels. In bare hull conditions the experimental roll peak was underestimated by the employed mathematical models for the largest steepness and this lack of agreement could be due to extrapolation difficulties for the roll damping mathematical model employed for the bare hull condition.

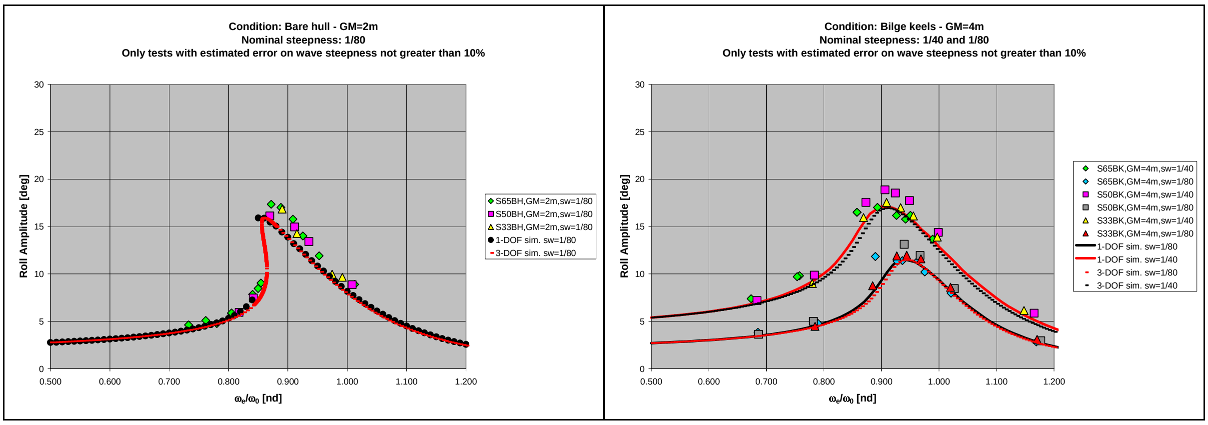

Figure 4: Experimental and simulated roll response curves.

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DISCLAIMER

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