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Ship Models

1. PURPOSE OF PROCEDURE

The purpose of the procedure is to ensure the correct manufacture of hull and propeller models for Resistance (including HSVMV Resistance), Propulsion and Propeller Open Water Tests.

The tolerances of propeller models for manoeuvring, sea keeping and ice tests can generally be larger (typically 1.5 to 2 times) than those used for propulsion or open water tests whilst those for cavitation tests may be smaller.

2. PARAMETERS

2.1 Definition of Variables

A_E	Expanded blade area (m^2)
A_0	Propeller disk area (m^2)
AP	After Perpendicular
B	Breadth (m)
c	Chord length (m)
D	Propeller diameter (m)
FP	Forward perpendicular
P	Propeller pitch (m)
L_{PP}	Length between perpendiculars (m)
L_{WL}	Length of waterline (*X*) (m)
Solidity factor	Ratio of assumed 2-*D* rotor blade area / disk area
T	Draught (m)
t	Blade section thickness (m)
X, *Y*, *Z*	Coordinate directions
Δ_m	Displacement Mass (kg)

3. DESCRIPTION OF PROCEDURE

3.1 Model Manufacture

3.1.1 Hull Model

General

The basic requirement is that the model should be geometrically similar to the ship wherever it is in contact with the water. This may not be possible in all cases owing to different systems and materials of construction on model scale and full size and it is desirable that any departures from similarity should be known and documented.

Materials and construction

Materials used for ship hull models include wax, wood, high-density closed cell foam and fibre reinforced plastic (FRP).

Models are normally cut from a lines plan re-drawn from the ship plan, or from a numerical definition of the hull surface stored electronically in an appropriate graphical format (e.g. IGES file or similar).

After cutting, the model is finished by hand. In the case of FRP construction, a foam or wooden plug of the model will be manufactured in a similar manner.

Surface finish

The model surface should be smooth and equivalent to that achieved with a 300 to 400 grit wet and dry paper.

Particular care should be taken when finishing the model to ensure that geometric features such as knuckles, spray rails, and boundaries of transom sterns remain well-defined, especially where flow separation is to be expected.

Stations and waterlines

The spacing and numbering of displacement stations and waterlines should be properly defined. Displacement *sections* may be identified as follows:

- A ten section system numbering from aft with station 0 at the *AP*. The number of stations can also be 21 (20 equally sized intervals). The stations are counted from aft.
- Decimal fraction stations may be introduced at the ends as required (such as 9.5, 9.6, 9.7 etc.).
- Stations aft of the *AP* to be numbered negatively.
- Stations forward of the *FP* to be numbered positively in natural succession (10.1, 10.2 etc.).

It should be noted that there are other methods of numbering the displacement stations, which may be equally acceptable.

Waterlines are identified as follows:

- Waterlines should be spaced as required and identified by their height above the baseline.
- The baseline should be defined as the topside of keel. In the case of a raked keel the baseline is parallel to the design waterline and midway between the height above base at the AP and FP stations.

Moulded dimensions:

Ship lines are normally drawn to moulded dimensions and model hulls should also be constructed to moulded dimensions.

Manufacturing tolerances

Model hull tolerances for breadth (Y) and depth (Z) should be within ± 1.0 mm. The tolerance for model length should be within ± 0.05%L_{PP} or ± 1.0 mm whichever is the larger.

For multihull models, the tolerances for transverse and longitudinal spacing of hulls should be within ± 0.05%L_{PP} or 1.0 mm whichever is the larger.

Openings: Openings in the hull should be manufactured to within ± 1.0 mm. Lateral thrust units should be modelled using an appropriate model of the thruster or a two-dimensional representation using an appropriate solidity factor.

Stability over time

The dimensions of the hull model should not move outside the recommended manufacturing tolerances. It should be noted that the dimensions of wax models can change appreciable with changes in temperature. For example, a change of 5^{0}C may alter the length of a model by about 0.15% (10 mm for a 7 m model). The model documentation should include any changes in dimensions, which may have arisen from this source.

3.1.2 Propeller Model

Manufacturing tolerances (for self propulsion and open water tests):

Propellers having diameter (D) typically from 150 mm to 300 mm should be finished to the following tolerances:

Diameter (D)	± 0.10 mm
Thickness (t)	± 0.10 mm
Blade width (c)	± 0.20 mm

Mean pitch at each radius (P/D): ± 0.5% of design value.

Special attention should be paid to the shaping accuracy near the leading and trailing edges of the blade section and to the thickness distributions. The propeller will normally be completed to a polished finish. The use of CAD/CAM processes further enhances the facility to achieve such tolerances.

The manufacture of model ducts, vane wheels and pre and post swirl vanes should follow the tolerances recommended above for model propellers used in self-propulsion and open water tests.

Gaps

The gap between the aft side of the model bossing and the fore side of the propeller boss should be the minimum required to allow sufficient forward movement of the propeller when calibrating the thrust dynamometer but should not exceed 2 mm with the propeller in its design position. Rope guards across the gap should not be produced at model scale.

Propeller / hull clearances

Propeller/hull aperture clearances should have tolerances within ± 1.0 mm and a maximum axial propeller movement of 1.5 mm. These tolerances should provide propeller clearances with less than 1.0% D error.

3.1.3 Appendages

Appendages in this context refer to items such as external shaft brackets, open propeller shafts, bossings, the struts and pods of podded propulsors, bilge keels, roll fins and rudders.

Appendages should be built to the full external shape as designed.

The manufacturing tolerances of appendages should be within ± 0.2 mm.

Surface finish should be at least as good as that recommended for the hull model.

Appendages should be located within ± 0.5 mm of their design position.

3.2 Turbulence Stimulation

3.2.1 Hull

The model should be fitted with a recognised turbulence stimulator, which should be clearly described in the model documentation and the report on the experiments. Suitable hull turbulence stimulators include studs, wires and sand grain strips. Figure 1, from Hughes and Allan (1951) and NPL Report 10/59 (1960), gives guidelines for the dimensions of studs and the location of the studs as turbulence stimulators on a raked stem of conventional type. A review of progress into the mechanisms of laminar-turbulent boundary layer transition and appropriate selection of devices for turbulence stimulation is given in Resistance Committee report for the 26th ITTC (2011).

Wires used for turbulence stimulation will be typically between 0.5 mm and 1.0 mm diameter, depending on position and model speed, and be situated about 5% L_{PP} aft of the FP.

<u>Sand strips</u> used for turbulence stimulation will typically comprise backing strips/adhesive of 5 mm to 10 mm width covered with sharp edged sand with grain size around 0.50 mm, with its leading edge situated about 5% L_{PP} aft of the *FP*.

A bulbous bow will additionally have turbulence stimulators situated typically at 1/3 of the bulb length from its fore end.

In the case of bulbous bows with S shaped waterlines the turbulence stimulator should be applied in a position short before a positive pressure gradient can be expected.

Appendages

Turbulence stimulation should be applied to appendages when laminar flow over the appendage is likely. Suitable turbulence stimulators for appendages include studs, wires, sand strips and Hama strips.

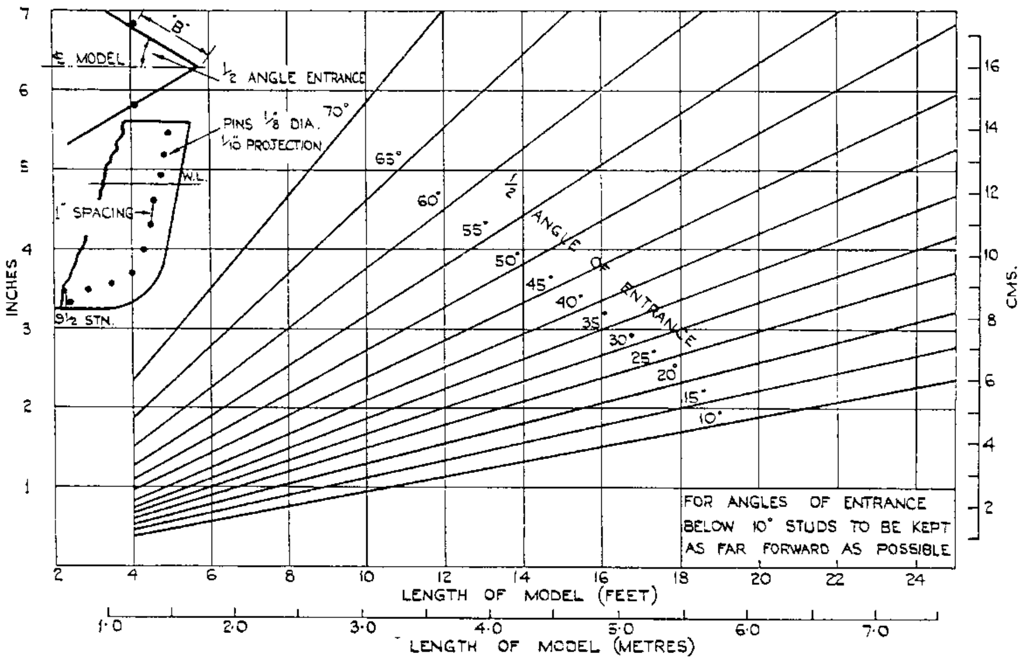

Figure 1 Location of studs as turbulence stimulators

3.2.2 Propeller

Turbulence stimulation will not normally be applied to propellers used in self-propulsion and open water tests. There is however evidence that turbulence stimulation may be necessary on model propellers used in cavitation tests.

3.3 Preparation for Model Testing

Before ballasting the model, careful checks of the model dimensions should be made.

3.3.1 Ballasting and trimming (for resistance and self propulsion tests)

The model should be loaded to give the correct volume displacement at model scale. This typically involves calculation of the full-scale volume displacement from knowledge of the full-scale weight and the appropriate water density; scaling of the volume displacement to model scale using the adopted scale factor; calculation of the model-scale weight using the water density appropriate for the tank; finally ballasting of the model to the calculated weight. The model weight should be correct to within 0.2% of the correct calculated weight displacement.

The trim of the model should be such that the errors in draught, if any, from the design figure are the same at the forward and after perpendiculars. The model will normally be tested without heel. The mean of the four draughts, fore perpendicular, after perpendicular, port side amidships and starboard side amidships, should not differ from the designed figure by more than 2.0mm or 0.05% L_{PP}, whichever is the less.

Hog or sag deformation should not exceed acceptable tolerances, typically not > 2.0 mm or 0.05% L_{PP}, whichever is less.

For older models being re-tested, the choice of an acceptable tolerance may depend on resistance benchmark re-tests.

3.3.2 Wax models

Before running, wax models should be left fully sunk in the water, preferably for 36 hours and not less than 12 hours. On re-floating, the entire surface should be cleaned in the tank water with a sponge or soft brush, particular care being taken to remove all air bubbles and slime from the surface. If the model has been in the water for some weeks and has become encrusted with a crystalline deposit it should be re-scraped and re-soaked, not merely sponged.

3.4 Documentation

The particulars of the model(s) should be collated in a report and/or included in a test report, and should contain at least the following information:

Hull Model:

Identification (model number or similar)

Materials of construction

Principal dimensions

Length between perpendiculars (L_{PP})

Length of waterline (L_{WL})

Breadth (B)

Draught (T)

For multihull vessels, longitudinal and transverse hull spacing

Design displacement (Δ) (kg, fresh water)

Hydrostatics, including water plane area and wetted surface area

Details of turbulence stimulation

Details of appendages

Tolerances of manufacture

Propeller Model:

Identification (model number or similar)

Materials of construction

Principal dimensions

Diameter

Pitch-Diameter Ratio (P/D)

Expanded blade Area Ratio (A_E/A_0)

Thickness Ratio (t/D)

Hub/Boss Diameter (d_h)

Tolerances of manufacture

4. REFERENCES

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