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Ships and marine technology — Model test method for propeller cavitation noise evaluation in ship design —

Part 1: Source level estimation

Navires et technologie maritime — Méthode d'essai sur modèle pour évaluer le bruit de cavitation des hélices dans la conception des navires —

Partie 1: Estimation du niveau d'émission de la source

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 8, *Ships and marine technology*, SC 8, *Ship design*.

Introduction

In order to reduce shipping noise, the characteristics of ship noise should be understood. Propeller noise, which is the major noise source in commercial ships, is mainly due to its turns as spectral harmonics and to cavitation as broadband noise. Special ships such as fishery research vessels and military vessels require quiet propellers with less or no cavitation in their operating conditions.

The propeller cavitation noise can be assessed by experimental and/or numerical methods in the propeller design stage. The numerical method such as CFD or empirical formulae might be a good alternative to propeller cavitation noise evaluations. However, the model tests are still used widely to predict the full-scale acoustic source strength of the propeller cavitation for a wide range of frequencies.

This document was developed to provide a standardized model test method for propeller cavitation noise evaluation. This document is aimed for appropriate evaluation of the propeller cavitation noise characteristics at the early design phase via model tests.

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Part 1: Source level estimation

1 Scope

This document specifies a model test method for propeller cavitation noise evaluation in ship design.

The procedure comprises reproduction of noise source, noise measurements, post processing and scaling. The target noise source is propeller cavitation. Thus, this document describes the test set-up and conditions to reproduce the cavitation patterns of the ship based on the similarity laws between the model and the ship. The propeller noise is measured at three stages. The measurement targets for each stage are propeller cavitation noise, background noise, and transmission loss. For the source level evaluations, corrections for the background noise and the transmission loss are applied to the measured propeller cavitation noise. Finally, the full-scale source levels are estimated from the model scale results using a scaling law.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 17208-1:2016, *Underwater acoustics — Quantities and procedures for description and measurement of underwater sound from ships — Part 1: Requirements for precision measurements in deep water used for comparison purposes*

IEC 61260, *Electroacoustics — Octave-band and fractional-octave-band filters*

ITTC — Recommended Procedures and Guidelines 7.5-02-01-05: *Model scale propeller cavitation noise measurements*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
acoustic centre
position where all the noise sources are co-located as a single point source

Note 1 to entry: The acoustic centre is the centre of the expected cavitation extent.

3.2
background noise
noise from all sources other than the source under test

3.3
cavitation number
σ_n
non-dimensional quantity defined as $\left(p_0 - p_v\right) / \left(\frac{1}{2}\rho n^2 D^2\right)$ where

p_0 is the total static pressure;

p_v is the vapour pressure;

ρ is the density of the fluid;

n is the propeller rotational speed (rps);

D is the diameter of the propeller.

Note 1 to entry: The total static pressure (p_0) consists of atmospheric pressure and submergence depth pressure which is usually taken at a specific point approximating the centre of the expected cavitation extent in the upper part of the disk, such as 0,7 R(R : radius of the propeller), 0,8 R or 0,9 R above the propeller centreline, although the propeller centreline is also used.

3.4
noise source
noise generating mechanism or object

Note 1 to entry: For the purposes of this document, the main noise source is the propeller cavitation.

3.5
propeller plane
imaginary plane orthogonal to the shaft centre line and including the intersection (point) of the shaft centre line and generator line

3.6
propeller thrust coefficient
K_T
non-dimensional quantity defined as $T/(\rho n^2 D^4)$, where T is the thrust of the propeller

3.7
propeller torque coefficient
K_Q
non-dimensional quantity defined as $Q/(\rho n^2 D^5)$, where Q is the torque of the propeller

3.8
reference distance
distance used for source level conversion and defined as 1 m apart from the acoustic centre

3.9
reference field
sound pressure field that is measured using a virtual source located at a given position, i.e. acoustic centre

Note 1 to entry: The reference field shall be used to calculate the source level.

3.10
sound pressure level
SPL
L_p
ten times the logarithm to the base 10 of the ratio of the time-mean-square pressure of the measured sound pressure, in a stated frequency band, to the square of a reference value expressed in decibels by

$L_p = 10 \log_{10}\left(\frac{p^2}{p_{ref}^2}\right)$ where $p_{ref} = 1 \mu Pa$

3.11
source level
SL
converted quantity of the measured sound pressure at a reference distance 1 m apart from the acoustic centre

3.12
virtual source
artificial sound source of which transmitting power is known *a priori*

3.13
wake
simulated ship wake at the propeller plane

Note 1 to entry: For the model test, ship wake is simulated using a wake screen or a ship model.

4 Model test setup and conditions

4.1 Test setup

In order to evaluate the propeller cavitation noise performance via model tests, it is important to reproduce noise sources accurately, i.e. the cavitation patterns, based on the similarity laws between the model and the ship. Test setup for the purpose comprises test facilities, model propellers, and wake fields generation.

4.1.1 Test facility

Test facilities might vary between variable pressure water tunnels, circulating water channels with a free surface in the test section to a depressurized towing tank. The variable pressure water tunnels, which are called cavitation tunnels, are widely used for the model tests. Depending on their test section sizes, suitable devices to generate wake fields should be utilized.

4.1.2 Model propeller

The size of a model propeller depends on the capacity constraint of the test facilities and on the acceptable range of test section blockage. The size of the model propeller should be determined to achieve the highest Reynolds number within the capacity constraints of the test facility. A typical propeller diameter for a model scale propeller is in the range between 180 mm to 300 mm. The accuracy of the model propeller geometry should be according to ITTC — Recommended Procedures and Guidelines 7.5-01-02-02[1] which specifies that the offsets of the blade sections should be in the range ±0,05 mm.

4.1.3 Wake generation

For the propeller cavitation model tests, the wake fields are to be generated by the wake screen or the model ship. In general, the former is used in small-sized and medium-sized cavitation tunnels, while the latter is used in the large cavitation tunnel. The important scaling parameter for the cavitation test is the Reynolds number but its similarity cannot be achieved for practical reasons. In order to reduce scale effect, the Reynolds number should be determined as high as possible within the capacity of the test facilities.

For the medium-sized cavitation tunnels, the wake distributions are to be generated inside the cavitation tunnel by using a wake screen composed of wire meshes. When a full-scale ship wake is required, it is to be obtained by extrapolating the model scale wake field or by using computational fluid dynamics (CFD). A dummy model in combination with wake screens can be applied in the medium-sized tunnel as well. For twin screw ships, the inclined shaft, brackets and bossing can be mounted in small- to medium-sized test sections.

For the large-sized cavitation tunnels, the wake can be generated typically from a ship model installed in the test section. In some cases, the ship model with grids or the shortened model can be used as well. The model ship is manufactured of various materials with the scale ratio that is dependent on the dimensions of the ship and the tunnel. The model ship is installed inside the tunnel corresponding to the full-scale draft. The free surface is covered by plates to suppress the wave interference to the model. The model ship draft in the tunnel is increased within the capacity constraint of the test facilities to compensate for the deceleration of the flow due to the boundary layer below these wave suppressing plates. The detailed configurations of the model are strictly based on the drawings of the full-scale ship. The accuracy of the model hull should be in accordance with ITTC — Recommended Procedures and Guidelines 7.5-01-01-01[2] which specifies a tolerance of ±1 mm. The maximum blockage of the ship model in the test section is in the order of 10 % to 20 %. A watertight dynamometer is to be installed together with an underwater motor aligned precisely to the propeller shaft inside the model ship. Thrust, torque and rotational speed of the model propeller are measured through the dynamometer.

The quality of the generated wake with respect to the target wake (measured wake in the towing tank or estimated full scale ship wake) should be assessed by wake field measurements using velocimetries, e.g. particle image velocimetry (PIV), laser Doppler velocimetry (LDV) or pitot tubes. Depending on the configuration one may measure the axial velocity component only, the axial and tangential velocity component or all three velocity components.

4.2 Test conditions

The cavitation test conditions are determined by the thrust identity method (or torque identity method) at discussed (or specified) self-propulsion point. In cavitation tests, the propeller operating condition is defined by the non-dimensional coefficients, propeller thrust coefficient K_T (or propeller torque coefficient K_Q) and cavitation number σ_n.

During the propeller cavitation observations and noise measurements the pressure in the cavitation tunnel is adjusted according to the local cavitation number at a specific point approximating the centre of the expected cavitation extent in the upper part of the disk, such as 0,7 R, 0,8 R or 0,9 R above the propeller centreline, although the propeller centreline is also used.

In the cavitation tunnel tests, inclusion of the effect of stern wave heights and sea margins for service conditions can be determined based on discussions with customers and/or experience of the model basin.

The air content of the water and the number and distribution of the cavitation nuclei play important roles in the cavitation inception and its development. Therefore, one or both of them should be considered based on experience of the test facilities.

For Froude scaled cavitation testing in a facility with a free surface, such as a depressurized towing tank or a free surface circulating water channel, the standard results of a Froude scaled towing basin powering test may be used directly to set the propeller RPM and speed for the various operating conditions of the experiment. It is noted that the usual procedure for scaling model powering results to full-scale is based on satisfying the thrust loading coefficient at full-scale Reynolds number, which is equivalent to a thrust identity approach.

For the measurement of cavitation noise in the cavitation tunnel and depressurized towing tank, it is necessary to stabilize the extent of cavitation since the cavitation noise slightly varies depending on the stability of cavitation extent[3]. There are several methodologies for stabilizing the extent of cavitation. One methodology is to add nuclei such as hydrogen microbubble in the water. Another methodology is to add roughness at the leading edge of the propeller blades at least on the back side.

Such treatments should be discussed in each facility by taking their standard experimental procedures into consideration, i.e. operation conditions including shaft speed and target velocity to be achieved, the scale of the model, water quality etc.

Although the extent of cavitation is stabilized by enough air content, depressurization in the cavitation tunnel and towing tank increases the number and the volume of bubbles in the water. Since the bubble attenuates the sound pressure, attention should be paid to the air content of the water in the cavitation tunnel and the depressurized towing tank.

