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Ships and marine technology — Guidelines for the assessment of speed and power performance by analysis of speed trial data

Navires et technologie maritime — Lignes directrices pour l'évaluation des performances de vitesse et de puissance par analyse des données d'essais de vitesse

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 15016 was prepared by Technical Committee ISO/TC 8, *Ships and marine technology*, Subcommittee SC 9, *General requirements*.

Annexes A to F form a normative part of this International Standard.

Introduction

This International Standard concerns the method of analysing the results obtained from speed trials.

The primary purpose of speed trials is to determine ship performance in terms of speed, power and propeller revolutions under prescribed ship conditions, and thereby verify the satisfactory attainment of the contractually stipulated ship speed. Ship speed is that realized under the contractually stipulated conditions which usually are no wind, no waves, no current, deep water, smooth hull and propeller surfaces.

Such stipulated conditions cannot normally all be expected to be met during the actual trials. In practice, certain corrections for the environmental conditions have to be considered, as for water depth, wind, waves and current.

The purpose of this International Standard is to define basic requirements for the performance of speed trials, and to provide procedures for evaluation and correction of speed trials covering all influences which may be relevant for the individual trial runs based on sound scientific grounds, thus giving confidence to the customer with respect to the final results.

The procedure specified in this International Standard has been derived largely on the basis of published data on speed trials and on ship performance, the more important among them being listed in normative annexes A to F.

Ships and marine technology — Guidelines for the assessment of speed and power performance by analysis of speed trial data

1 Scope

This International Standard specifies the procedure to be applied in analysing the results of speed trials for ships, with reference to the effects which may have an influence upon the speed-power-revolutions relationship.

The applicability of this International Standard is limited to commercial ships of the displacement type.

The instrumentation to be used in the speed trials is not specifically indicated, nor is the method of conducting the trials. Calibrated instruments and their methods of use commonly adopted for such trials should be acceptable.

In this International Standard, it was decided that the unit to express the amount of an angle should be “rad” (radian) and that the unit of speed should be “m/s” (metres per second). Nevertheless, “°” (degree) as a unit for an angle and “kn” (knot) as a unit for speed may be used. However, the units for the angles and speeds which appear in calculation formulas are to be “rad” and “m/s” without exception. Moreover, for the convenience of the users of this standard, numerical values using the units of degree and knot are stated jointly at appropriate places.

2 Terms and definitions

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

2.1
propeller pitch
design pitch for controllable pitch propellers

2.2
brake power
power delivered by the output coupling of the propulsion machinery before passing through any speed-reducing and transmission devices and with all continuously operating engine auxiliaries in use

2.3
shaft power
net power supplied by the propulsion machinery to the propulsion shafting after passing through all speed-reducing and other transmission devices and after power for all attached auxiliaries has been taken off

3 Symbols and abbreviations

3.1 Symbols

A_M : area of midship section under water

A_R : rudder area

A_{XV} : area of maximum transverse section exposed to wind (area of portion of ship above waterline projected normally to the longitudinal direction of ship)

B : breadth, moulded, of ship

b_R : rudder span

C_{AA} : wind resistance coefficient

C_{AA0} : wind resistance coefficient in head wind

C_B : block coefficient

C_F : frictional resistance coefficient

C_T : total resistance coefficient

D : propeller diameter

f : frequency

F_n : Froude number

g : acceleration due to gravity

h : water depth

H : total wave height

$H_{1/3}$: significant wave height of seas

$H_{S1/3}$: significant wave height of swell

J : propeller advance ratio

k : wave number

$K(\psi_{WR})$: directional coefficient of wind resistance

K_Q : torque coefficient

K_{QO} : torque coefficient of propeller converted from behind to open water condition

K_T : thrust coefficient

L_{pp} : length of ship between perpendiculars

m : mass in general

n : propeller frequency of revolutions

P : propeller pitch

P_B : brake power

P_D : delivered power

P_S : shaft power (= 2 $\pi n Q$)

Q : shaft torque

R : resistance in general

R_{AA} : resistance increase due to wind

R_{ADIS} : resistance increase due to displacement

R_{AS} : resistance increase due to temperature and salt content

R_F : frictional resistance

R_T : total resistance

R_{AW} : resistance increase due to waves

$R_{\beta\beta}$: resistance increase due to drifting

$R_{\delta\delta}$: resistance increase due to steering

$S(f)$: spectral density function of unidirectional waves

S_R : real slip ratio

S_W : wetted surface area

t : thrust deduction fraction

T : period or temperature in general

T_{01} : average period from zeroth and first moment

T_{02} : average period from zeroth and second moment

T_m : mean wave period of seas

t_R : resistance deduction fraction due to steering

T_{Sm} : mean wave period of swell

T_W : water temperature

V_{eff} : effective inflow velocity to rudder

V_F : current velocity

V_G : ship's speed over the ground

V_S : ship's speed through the water

V_{WR} : relative wind velocity

V_{WT} : true wind velocity

w : Taylor wake fraction in general

β : drift angle

δ_R : rudder angle

Δ : displacement force

ΔR : total resistance increase

Δr : response increase due to regular waves ($= \Delta r_1 + \Delta r_2$)

Δr_1 : resistance increase due to radiation in regular waves

Δr_2 : resistance increase due to diffraction in regular waves

ζ_A : wave amplitude

η : efficiency in general

η_R : relative rotative efficiency

η_T : transmission efficiency: ratio P_D / P_S or P_D / P_B

λ_R : aspect ratio of rudder

π : $= 3{,}141\,592\,6$

ρ : mass density in general

ρ_A : mass density of air

τ : load factor $\left(R / \rho D^2 V_S^2 (1-w)^2 (1-t) = K_T / J^2 \right)$

χ : incident angle of waves (head wave: $\chi = \pi$ rad)

ψ_A : yaw amplitude

ψ_0 : course direction

ψ_{WR} : relative wind direction: positive direction from which the wind is blowing; head wind = 0 (0°)

ψ_{WA} : true wind direction: positive direction from which the wind is blowing; wind from the north = 0 (0°)

ν : kinematic viscosity

ω : circular frequency of incident waves

ω_e : circular frequency of encounter

3.2 Abbreviations

BSRA: The British Ship Research Association

ITTC: International Towing Tank Conference

JTTC: Japan Towing Tank Committee

KSNAJ: The Kansai Society of Naval Architects, Japan

RINA: Royal Institute of Naval Architects, UK

SNAJ: The Society of Naval Architects of Japan

SNAME: The Society of Naval Architects and Marine Engineers, USA

SRAJ: The Shipbuilding Research Association of Japan

WJSNAJ: The West — Japan Society of Naval Architects

4 Trial conditions

4.1 Wind

Wind speed and direction shall be measured as relative wind using the ship's wind indicator. Continuous recording of the relative wind during each run is recommended.

Whenever possible, wind force during the speed trials shall not be higher than

— Beaufort Number 6, $L_{pp} \geqslant 100$ m, or

— Beaufort Number 5, $L_{pp} < 100$ m.

4.2 Sea state

If possible, instruments should be used to determine the wave height, wave period and direction of seas and swell, as buoys or instruments onboard the ships (e.g. seaway analysis radar). Wave characteristics may be determined from observations by multiple observers, including the captain, preferably supported by hindcasting if the expected effect of the seaway is significant.

The total wave height, H, which is the sum of significant wave heights of seas $H_{1/3}$ and swell $H_{S1/3}$, shall satisfy the following:

$$L_{pp} \geqslant 100 \text{ m} : \text{the lower value of } H \leqslant 0{,}015 L_{pp} \text{ or } 3 \text{ m} \quad (1)$$

$$L_{pp} < 100 \text{ m} : H \leqslant 1{,}5 \text{ m}$$

where

$$H = \sqrt{H_{1/3}^2 + H_{S1/3}^2} \text{ (m)}; \quad (2)$$

L_{pp} is the length of ship between perpendiculars, in metres.

4.3 Water depth

Water depth in the trial area shall be obtained either from sea charts or by means of echo-sounder measurements.

To obtain satisfactory results, the water depth shall satisfy the following:

$$\Delta V_S / V_S \leqslant 0{,}02 \quad (3)$$

where

V_S is the ship's speed, in metres/second;

ΔV_S is the ship's speed loss due to shallow water, in metres/second

The ship's speed loss due to the effect of shallow water can be derived from normative annex F.

4.4 Current

Current speed and direction shall be obtained either as part of the evaluation of run and counter-run of each double run or by direct measurement with a current gauge buoy.

5 Speed and power measurement

5.1 Runs

All speed trials shall be carried out using double runs, i.e. each run followed by a return run in the exact opposite direction performed with the same engine settings. The number of such double runs shall not be less than three. Preferably runs should be performed in head and following winds.

Each run shall be preceded by an approach run, which shall be of sufficient length to attain steady running conditions.

5.2 Steering

The single amplitude of variation of heading angle, ψ_A, shall be within π/60 rad (3°).

The counter rudder to maintain a straight course shall be within π/36 rad (5°).

5.3 Measured and observed data

5.3.1 General data

Prior to the trial, the data specified below shall be recorded, based on measurements where relevant:

— date;

— area of trial;

— weather;

— mean water depth in area of trial;

— water temperature and density;

- air temperature;
- height of wind instrument above waterline;
- fore, midships and aft draughts;
- displacement;
- propeller pitch in the case of CPP.

It is recommended to retain a record of the following factors, which should prove useful for verifying the condition of the ship at the time of the speed trial:

- time elapsed since last hull and propeller cleaning;
- surface condition of hull and propeller.

5.3.2 Data on each run

The following data shall be monitored and recorded on each run:

- clock time at commencement;
- time elapsed over the measured distance;
- course direction;
- ship's speed over ground;
- propeller frequency of revolutions;
- propeller shaft torque and/or brake power;
- relative wind velocity and direction;
- mean wave period, significant wave height and direction of waves (seas);
- mean wave period, significant wave height and direction of waves (swell);
- rudder angle;
- drift angle.

There are two kinds of power, one is shaft power and the other is brake power. Shaft power shall be calculated by means of measuring shaft speed and torque of the shaft. Both types of power can be used to evaluate the speed and power performance. The analysis procedure in clause 6 uses shaft power.

Data such as ship's speed, frequency of revolutions of the propeller, torque, rudder angle, and drift angle to be used for analyses shall be the average values derived on the measured distance. If the draughts are needed for each run, they may be estimated using a loading computer, based on the data prior to the trial and the fuel consumption up to that time.

6 Analysis procedure

6.1 Flow of trial analysis

The analysis of trial data is basically divided into the following six steps, as shown in Figure 1.

a) Step 1: evaluation of acquired trial data.

b) Step 2: correction of ship's performance for resistance increase.

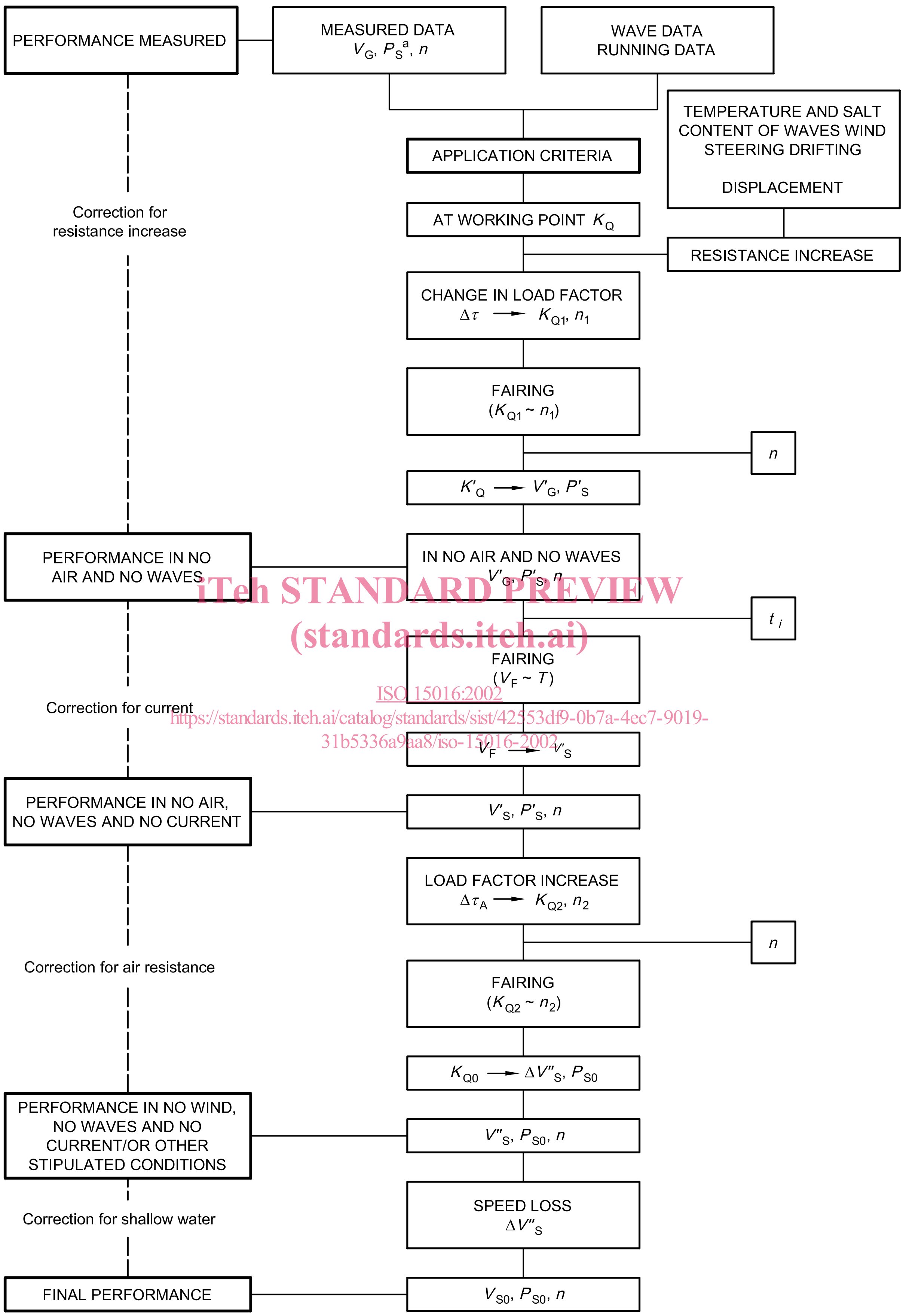
c) Step 3: correction of ship's performance for current.

d) Step 4: correction of ship's performance for air resistance.

e) Step 5: correction of ship's performance for shallow water.

f) Step 6: final ship's performance.

The procedure is described by reference to the numbered columns in Table 1.



[a] P_B may be used alternatively.

Figure 1 — Flowchart of speed trial analysis