

**BS ISO 13643-6:2017**



**BSI Standards Publication**

# **Ships and marine technology — Manoeuvring of ships**

Part 6: Model test specials

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**National foreword**

This British Standard is the UK implementation of ISO 13643-6:2017. It supersedes BS ISO 13643-6:2013 which is withdrawn.

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# INTERNATIONAL STANDARD

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**13643-6**

Second edition  
2017-02

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## **Ships and marine technology — Manoeuvring of ships —**

### **Part 6: Model test specials**

*Navires et technologie maritime — Manoeuvres des navires —  
Partie 6: Spécificités des essais sur modèle*



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# Contents

Page

|                                                                            |           |
|----------------------------------------------------------------------------|-----------|
| <b>Foreword</b>                                                            | <b>iv</b> |
| <b>1 Scope</b>                                                             | <b>1</b>  |
| <b>2 Normative references</b>                                              | <b>1</b>  |
| <b>3 Terms and definitions</b>                                             | <b>1</b>  |
| <b>4 Test-related physical quantities</b>                                  | <b>2</b>  |
| <b>5 General test conditions</b>                                           | <b>19</b> |
| <b>6 Test 6.1 — Planar motion test</b>                                     | <b>19</b> |
| 6.1 General                                                                | 19        |
| 6.2 Description                                                            | 21        |
| 6.3 Analysis and presentation of results of a planar motion test           | 22        |
| 6.3.1 Tests in the horizontal plane of motion                              | 22        |
| 6.3.2 Tests in the vertical plane of motion (for submarines only)          | 28        |
| 6.3.3 Tests for angular motion about x-axis (roll)                         | 31        |
| 6.4 Designation of a planar motion test                                    | 32        |
| 6.4.1 Designation of a planar motion test in the horizontal plane (H)      | 32        |
| 6.4.2 Designation of a planar motion test in the vertical plane (V)        | 33        |
| 6.4.3 Designation of a planar motion test for roll motion (R)              | 33        |
| <b>7 Test 6.2 — Circular motion test</b>                                   | <b>33</b> |
| 7.1 General                                                                | 33        |
| 7.2 Description                                                            | 34        |
| 7.3 Analysis and presentation of results of a circular motion test         | 34        |
| 7.4 Designation of a circular motion test                                  | 34        |
| <b>8 Test 6.3 — Oblique towing or flow test</b>                            | <b>36</b> |
| 8.1 General                                                                | 36        |
| 8.2 Description                                                            | 37        |
| 8.3 Analysis and presentation of results of an oblique towing or flow test | 37        |
| 8.4 Designation of an oblique towing or flow test                          | 37        |
| <b>9 Test 6.4 — Wind tunnel test</b>                                       | <b>40</b> |
| 9.1 General                                                                | 40        |
| 9.2 Description                                                            | 40        |
| 9.3 Analysis and presentation of results of a wind tunnel test             | 40        |
| 9.4 Designation of a wind tunnel test                                      | 41        |

## 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.

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](http://www.iso.org/directives)).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

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For an explanation on 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](http://www.iso.org/iso/foreword.html).

The committee responsible for this document is ISO/TC 8, *Ships and marine technology*, Subcommittee SC 6, *Navigation and ship operations*.

This second edition cancels and replaces the first edition (ISO 13643-6:2013), of which it constitutes a minor revision with the following changes:

- in [3.6](#)  $\psi$ -carriage was inserted;
- in [Table 1](#) “DNDPDYS” row, the symbol was changed from “ $N_{\phi\text{dyn}}$ ” to “ $N'_{\phi\text{dyn}}$ ”;
- in [Table 1](#) “DYDVTS” row, the SI-unit was changed from “—” to “1”;
- in [Equation \(20\)](#) “ $\rho_w$ ” was changed to “ $\rho$ ”;
- in [7.3](#) paragraph 3, “moments” was changed to “motions”.

A list of all parts in the ISO 13643 series can be found on the ISO website.

# Ships and marine technology — Manoeuvring of ships —

## Part 6: Model test specials

### 1 Scope

This document defines symbols and terms and provides guidelines for the conduct of tests to determine the hydrodynamic forces and moments due to prescribed motions under a planar-motion, a circular-motion or an oblique towing or flow system for models of surface ships and submarines. It also defines symbols and terms and provides guidelines for the conduct of tests in a wind tunnel. It is intended to be read in conjunction with ISO 13643-1.

### 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 13643-1, *Ships and marine technology — Manoeuvring of ships — Part 1: General concepts, quantities and test conditions*

### 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

##### **planar motion test**

manoeuvring test to determine the hydrodynamic forces and moments as functions of lateral velocity and acceleration as well as of angular velocity and acceleration about the z-axis or the y-axis, respectively

#### 3.2

##### **circular motion test**

manoeuvring test to determine the hydrodynamic forces and moments as a function of the angular velocity for surface ships primarily about the z-axis, for submarines primarily about the z-axis, as well as the y-axis

#### 3.3

##### **oblique towing or flow test**

manoeuvring test to determine the forces and moments as a function of the drift angle and of the manoeuvring device angle and, in the case of submarines, the angle of attack and hydroplane deflections, in a towing tank, a circulating water tunnel, or a wind tunnel

### 3.4 wind tunnel test

test to determine the aerodynamic forces and moments acting upon the above-water portion of the ship as a function of the relative wind

Note 1 to entry: A wind tunnel may also be used for the underwater hull.

### 3.5 manoeuvring device

rudder, azimuthing thruster, hydroplane, cycloidal propeller or equivalent system used to manoeuvre a vessel

### 3.6 $\psi$ -carriage

sub carriage (secondary towing system) to the towing carriage that allows a differential longitudinal, a transverse and a rotational motion of the model in the horizontal plane

## 4 Test-related physical quantities

Test-related physical quantities are according to [Table 1](#). General quantities and concepts are according to ISO 13643-1.

**Table 1 — Test-related physical quantities**

| Symbol    | CC-code | SI-unit        | Concept                                           |                                                                                   |
|-----------|---------|----------------|---------------------------------------------------|-----------------------------------------------------------------------------------|
|           |         |                | Term                                              | Definition or explanation                                                         |
| $A_{LV}$  | ALV     | m <sup>2</sup> | Lateral area above waterline                      | (see ISO 13643-1)                                                                 |
| $A_{XV}$  | AXV     | m <sup>2</sup> | Transverse projected area of ship above waterline | Projected cross section area above DWL, generally without rigging, railings, etc. |
| AP        | AP      | —              | After perpendicular                               | (see ISO 13643-1)                                                                 |
| $a_0$     | A0PMM   | m              | Displacement amplitude of the model movement      | —                                                                                 |
| C         | CWI     | N              | Cross force                                       | Force perpendicular to relative wind direction                                    |
| $C_C$     | CC      | 1              | Cross force coefficient                           | $2C / (\rho_A V_{WRA}^2 A_{LV})$                                                  |
| $C_D$     | CD      | 1              | Drag coefficient                                  | $2D / (\rho_A V_{WRA}^2 A_{LV})$                                                  |
| $C_{DAX}$ | CDAX    | 1              | Drag coefficient                                  | $2D / (\rho_A V_{WRA}^2 A_{XV})$ , relative to cross section                      |
| $C_K$     | CK      | 1              | Roll-moment coefficient                           | $2K / (\rho_A V_{WRA}^2 A_{LV} L_{OA})$                                           |
| $C_N$     | CN      | 1              | Coefficient of moment about z-axis                | $2N / (\rho_A V_{WRA}^2 A_{LV} L_{OA})$                                           |
| $C_X$     | CX      | 1              | Longitudinal-force coefficient                    | $2X / (\rho_A V_{WRA}^2 A_{LV})$                                                  |
| $C_{XAX}$ | CXAX    | 1              | Longitudinal-force coefficient                    | $2X / (\rho_A V_{WRA}^2 A_{XV})$ , relative to cross section                      |
| $C_Y$     | CY      | 1              | Lateral-force coefficient                         | $2Y / (\rho_A V_{WRA}^2 A_{LV})$                                                  |

Table 1 (continued)

| Symbol                | CC-code | SI-unit                 | Concept                                            |                                                                                                                                                                       |
|-----------------------|---------|-------------------------|----------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                       |         |                         | Term                                               | Definition or explanation                                                                                                                                             |
| $D$                   | DWI     | N                       | Drag                                               | Force in direction in which relative wind blows                                                                                                                       |
| DWL                   | DWL     | —                       | Design waterline                                   | (see ISO 13643-1)                                                                                                                                                     |
| FP                    | FP      | —                       | Fore perpendicular                                 | (see ISO 13643-1)                                                                                                                                                     |
| $F_T$                 | FTWI    | N                       | Resultant force                                    | $\sqrt{C^2 + D^2}$ and $\sqrt{X^2 + Y^2}$ , respectively                                                                                                              |
| $F_n$                 | FN      | 1                       | Froude number                                      | (see ISO 13643-1)                                                                                                                                                     |
| $F_{n0}$              | FN0     | 1                       | (Reference) Froude number                          | $v_0 / \sqrt{gL}$                                                                                                                                                     |
| $\overline{GM}$       | GM      | m                       | Metacentric height                                 | (see ISO 13643-1)                                                                                                                                                     |
| $H_{LM}$              | HLM     | m                       | Mean height of lateral area above design waterline | $A_{LV}/L_{OA}$                                                                                                                                                       |
| $I_{xx}$              | IXX     | kg m <sup>2</sup>       | Moment of inertia of the model about x-axis        | (see ISO 13643-1)                                                                                                                                                     |
| $I_{yy}$              | IYY     | kg m <sup>2</sup>       | Moment of inertia of the model about y-axis        | (see ISO 13643-1)                                                                                                                                                     |
| $I_{zx}$              | IZX     | kg m <sup>2</sup>       | Product of inertia of the model                    | (see ISO 13643-1)                                                                                                                                                     |
| $I_{zz}$              | IZZ     | kg m <sup>2</sup>       | Moment of inertia of the model about z-axis        | (see ISO 13643-1)                                                                                                                                                     |
| $K$                   | MX      | N m                     | Roll moment                                        | Moment about x-axis<br>Relative to ship-fixed axis system                                                                                                             |
| $K_{\phi\text{stat}}$ | DKDPST  | N m rad <sup>-1</sup> a | —                                                  | $\frac{\partial K}{\partial \phi} \big _{V=0}$<br>from static test or calculation                                                                                     |
| $K'$                  | MXS     | 1                       | Non-dimensional roll moment                        | Especially for submarines:<br>$\frac{K}{\frac{\rho}{2} L^3 V^2}$<br>where $K(u, v, w, p, q, r, \dot{v}, \dot{w}, \dot{p}, \dot{q}, \dot{r}, \phi, \theta)$            |
|                       |         |                         |                                                    | For surface ships only:<br>$\frac{K}{\frac{\rho}{2} L^3 V_0^2}$<br>where $K(V_0, \Delta u, v, w, p, q, r, \dot{v}, \dot{w}, \dot{p}, \dot{q}, \dot{r}, \phi, \theta)$ |
| $K'_{\text{in}}$      | MXINS   | 1                       | In-phase part of non-dimensional roll moment       | $\frac{2}{nT} \int_t^{t+nT} K'(t) \sin \omega t \, dt$                                                                                                                |
| $K'_{\text{out}}$     | MXOUTS  | 1                       | Quadrature part of non-dimensional roll moment     | $\frac{2}{nT} \int_t^{t+nT} K'(t) \cos \omega t \, dt$                                                                                                                |

**Table 1** (continued)

| Symbol                              | CC-code  | SI-unit | Concept                                                                                                    |                                                                         |
|-------------------------------------|----------|---------|------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|
|                                     |          |         | Term                                                                                                       | Definition or explanation                                               |
| $K'_p$                              | DKDPS    | 1       | —                                                                                                          | $\left. \frac{\partial K'}{\partial p'} \right _{K'=\hat{K}'_0}$        |
| $K'_{\dot{p}}$                      | DKDPTS   | 1       | —                                                                                                          | $\left. \frac{\partial K'}{\partial \dot{p}'} \right _{K'=\hat{K}'_0}$  |
| $K'_{\ddot{p}}$                     | DKDP3TS  | 1       | —                                                                                                          | $\left. \frac{\partial K'}{\partial \ddot{p}'} \right _{K'=\hat{K}'_0}$ |
| $K'_r$                              | DKDRS    | 1       | Slope through zero of $K'$ versus $r'$                                                                     | $\left. \frac{\partial K'}{\partial r'} \right _{K'=\hat{K}'_0}$        |
| $K'_{\dot{r}}$                      | DKDRTS   | 1       | —                                                                                                          | $\left. \frac{\partial K'}{\partial \dot{r}'} \right _{K'=\hat{K}'_0}$  |
| $K'_v$                              | DKDVS    | 1       | Slope through zero of $K'$ versus $v'$                                                                     | $\left. \frac{\partial K'}{\partial v'} \right _{K'=\hat{K}'_0}$        |
| $K'_{\dot{v}}$                      | DKDVTs   | 1       | —                                                                                                          | $\left. \frac{\partial K'}{\partial \dot{v}'} \right _{K'=\hat{K}'_0}$  |
| $\hat{K}'_{pq}$                     | MXPQS    | 1       | Non-dimensional coefficient used in representing $K'$ as a function of $p' q'$                             | —                                                                       |
| $\hat{K}'_r$                        | MXRS     | 1       | Non-dimensional coefficient used in representing $K'$ as a function of $F_{n0} r'$                         | (for surface ships only)                                                |
| $\hat{K}'_{ur}$                     | MXURS    | 1       | Non-dimensional coefficient used in representing $K'$ as a function of $u' r'$                             | (especially for submarines)                                             |
| $\hat{K}'_{uu}$                     | MXUUS    | 1       | Non-dimensional coefficient used in representing $K'$ as a function of $u'^2$                              | (especially for submarines)                                             |
| $\hat{K}'_{uu\delta R}$             | MXUUDRS  | 1       | Non-dimensional coefficient used in representing $K'$ as a function of $u'^2 \delta_R$                     | (especially for submarines)                                             |
| $\hat{K}'_{uu\delta\delta\delta R}$ | MXUUDR3S | 1       | Non-dimensional coefficient used in representing $K'$ as a function of $u'^2 \delta_R^3$                   | (especially for submarines)                                             |
| $\hat{K}'_{uv}$                     | MXUVS    | 1       | Non-dimensional coefficient used in representing $K'$ as a function of $u' v'$                             | (especially for submarines)                                             |
| $\hat{K}'_{uv\delta R}$             | MXUVDRS  | 1       | Non-dimensional coefficient used in representing $K'$ as a function of $u' v' \delta_R$                    | (especially for submarines)                                             |
| $\hat{K}'_v$                        | MXVS     | 1       | Non-dimensional coefficient used in representing $K'$ as a function of $F_{n0} v'$                         | (for surface ships only)                                                |
| $\hat{K}'_{vvv}$                    | MXV3S    | 1       | Non-dimensional coefficient used in representing $K'$ as a function of $v'  v'  \sqrt{v'^2 + w'^2} F_{n0}$ | (for surface ships only)                                                |

Table 1 (continued)

| Symbol                              | CC-code | SI-unit                 | Concept                                                                                                                                                   |                                                                                                                      |
|-------------------------------------|---------|-------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------|
|                                     |         |                         | Term                                                                                                                                                      | Definition or explanation                                                                                            |
| $\hat{K}'_{v v}$                    | MXVVAS  | 1                       | Non-dimensional coefficient used in representing $K'$ as a function of $v' \sqrt{v'^2 + w'^2}$                                                            | —                                                                                                                    |
| $\hat{K}'_{v\delta R}$              | MXVDRS  | 1                       | Non-dimensional coefficient used in representing $K'$ as a function of $F_{n0} v' \delta_R$                                                               | (for surface ships only)                                                                                             |
| $\hat{K}'_{wp}$                     | MXWPS   | 1                       | Non-dimensional coefficient used in representing $K'$ as a function of $w' p'$                                                                            | —                                                                                                                    |
| $\hat{K}'_{wr}$                     | MXWRS   | 1                       | Non-dimensional coefficient used in representing $K'$ as a function of $w' r'$                                                                            | —                                                                                                                    |
| $\hat{K}'_{\Delta u}$               | MXDUS   | 1                       | Non-dimensional coefficient used in representing $K'$ as a function of $\Delta u'$                                                                        | (for surface ships only)                                                                                             |
| $\hat{K}'_{\Delta uv}$              | MXDUVS  | 1                       | Non-dimensional coefficient used in representing $K'$ as a function of $\Delta u' v'$                                                                     | (for surface ships only)                                                                                             |
| $\hat{K}'_{\Delta \Delta u}$        | MXDU2S  | 1                       | Non-dimensional coefficient used in representing $K'$ as a function of $(\Delta u')^2$                                                                    | (for surface ships only)                                                                                             |
| $\hat{K}'_{\delta R}$               | MXDRS   | 1                       | Non-dimensional coefficient used in representing $K'$ as a function of $F_{n0}^2 \delta_R$                                                                | (for surface ships only)                                                                                             |
| $\hat{K}'_{\delta \delta \delta R}$ | MXDR3S  | 1                       | Non-dimensional coefficient used in representing $K'$ as a function of $F_{n0}^2 \delta_R^3$                                                              | (for surface ships only)                                                                                             |
| $\hat{K}'_0$                        | MX0S    | 1                       | Non-dimensional coefficient used in representing $K'$ when angle of attack $\alpha$ , drift angle $\beta$ , manoeuvring device, and plane angles are zero | —                                                                                                                    |
| $\hat{K}'_{\phi}$                   | MXOPHS  | 1                       | Non-dimensional oscillatory roll coefficient                                                                                                              | —                                                                                                                    |
| $L$                                 | L       | m                       | Model length                                                                                                                                              | Reference length (see ISO 13643-1)                                                                                   |
| $L_{OA}$                            | LOA     | m                       | Length overall                                                                                                                                            | Length between the most aft and most forward points of the ship, permanent outfit included, measured parallel to DWL |
| $M$                                 | MY      | N m                     | Moment about y-axis                                                                                                                                       | Relative to ship-fixed axis system                                                                                   |
| MA                                  | MAX     | —                       | Main axis                                                                                                                                                 | (see ISO 13643-1)                                                                                                    |
| $M_{\theta \text{stat}}$            | DMDTST  | N m rad <sup>-1</sup> a | —                                                                                                                                                         | $\frac{\partial M}{\partial \theta} \big _{V=0}$<br>from static test or calculation                                  |

**Table 1** (continued)

| Symbol          | CC-code | SI-unit             | Concept                                                                        |                                                                                                                                                                    |
|-----------------|---------|---------------------|--------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                 |         |                     | Term                                                                           | Definition or explanation                                                                                                                                          |
| $M'$            | MYS     | 1                   | Non-dimensional moment about y-axis                                            | Especially for submarines<br>$\frac{M}{\frac{\rho}{2} L^3 V^2}$ where $M(u, v, w, p, q, r, \dot{v}, \dot{w}, \dot{p}, \dot{q}, \dot{r}, \phi, \theta)$             |
|                 |         |                     |                                                                                | For surface ships only:<br>$\frac{M}{\frac{\rho}{2} L^3 V_0^2}$ where $M(V_0, \Delta u, v, w, p, q, r, \dot{v}, \dot{w}, \dot{p}, \dot{q}, \dot{r}, \phi, \theta)$ |
| $M'_{in}$       | MYINS   | 1                   | In-phase part of non-dimensional moment about y-axis                           | $\frac{2}{nT} \int_t^{t+nT} M'(t) \sin \omega t \, dt$                                                                                                             |
| $M'_{out}$      | MYOUTS  | 1                   | Quadrature part of non-dimensional moment about y-axis                         | $\frac{2}{nT} \int_t^{t+nT} M'(t) \cos \omega t \, dt$                                                                                                             |
| $M'_q$          | DMDQS   | 1                   | Slope through zero of $M'$ versus $q'$                                         | $\left. \frac{\partial M'}{\partial q'} \right _{M'=\hat{M}'_0}$                                                                                                   |
| $M'_{\dot{q}}$  | DMDQTS  | 1                   | —                                                                              | $\left. \frac{\partial M'}{\partial \dot{q}'} \right _{M'=\hat{M}'_0}$                                                                                             |
| $M'_{\ddot{q}}$ | DMDQ3TS | 1                   | —                                                                              | $\left. \frac{\partial M'}{\partial \ddot{q}'} \right _{M'=\hat{M}'_0}$                                                                                            |
| $M'_w$          | DMDWS   | 1                   | Slope through zero of $M'$ versus $w'$                                         | $\left. \frac{\partial M'}{\partial w'} \right _{M'=\hat{M}'_0}$                                                                                                   |
| $M'_{\dot{w}}$  | DMDWTS  | 1                   | —                                                                              | $\left. \frac{\partial M'}{\partial \dot{w}'} \right _{M'=\hat{M}'_0}$                                                                                             |
| $M'_\theta$     | DMDTHS  | rad <sup>-1</sup> a | —                                                                              | $\left. \frac{\partial M'}{\partial \theta} \right _{M'=\hat{M}'_0}$                                                                                               |
| $\hat{M}'_{pp}$ | MYPPS   | 1                   | Non-dimensional coefficient used in representing $M'$ as a function of $p'^2$  | —                                                                                                                                                                  |
| $\hat{M}'_{pr}$ | MYPRS   | 1                   | Non-dimensional coefficient used in representing $M'$ as a function of $p' r'$ | —                                                                                                                                                                  |

Table 1 (continued)

| Symbol                  | CC-code | SI-unit | Concept                                                                                                                                                   |                           |
|-------------------------|---------|---------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------|
|                         |         |         | Term                                                                                                                                                      | Definition or explanation |
| $\hat{M}'_q$            | MYQS    | 1       | Non-dimensional coefficient used in representing $M'$ as a function of $u' q'$                                                                            | —                         |
| $\hat{M}'_{q q }$       | MYQQAS  | 1       | Non-dimensional coefficient used in representing $M'$ as a function of $q' q' $                                                                           | —                         |
| $\hat{M}'_{q \delta S}$ | MYQADSS | 1       | Non-dimensional coefficient used in representing $M'$ as a function of $u' q' \delta_S$                                                                   | —                         |
| $\hat{M}'_{rr}$         | MYRRS   | 1       | Non-dimensional coefficient used in representing $M'$ as a function of $r'^2$                                                                             | —                         |
| $\hat{M}'_{uu}$         | MYUUS   | 1       | Non-dimensional coefficient used in representing $M'$ as a function of $u'^2$                                                                             | —                         |
| $\hat{M}'_{vp}$         | MYVPS   | 1       | Non-dimensional coefficient used in representing $M'$ as a function of $v' p'$                                                                            | —                         |
| $\hat{M}'_{vr}$         | MYVRS   | 1       | Non-dimensional coefficient used in representing $M'$ as a function of $v' r'$                                                                            | —                         |
| $\hat{M}'_w$            | MYWS    | 1       | Non-dimensional coefficient used in representing $M'$ as a function of $u' w'$                                                                            | —                         |
| $\hat{M}'_{ww}$         | MYWWS   | 1       | Non-dimensional coefficient used in representing $M'$ as a function of $ w'  \sqrt{v'^2 + w'^2}$                                                          | —                         |
| $\hat{M}'_{w w }$       | MYWWAS  | 1       | Non-dimensional coefficient used in representing $M'$ as a function of $w' \sqrt{v'^2 + w'^2}$                                                            | —                         |
| $\hat{M}'_{ w }$        | MYWAS   | 1       | Non-dimensional coefficient used in representing $M'$ as a function of $u' w' $                                                                           | —                         |
| $\hat{M}'_{ w q}$       | MYWAQS  | 1       | Non-dimensional coefficient used in representing $M'$ as a function of $q' \sqrt{v'^2 + w'^2}$                                                            | —                         |
| $\hat{M}'_{\delta B}$   | MYDBS   | 1       | Non-dimensional coefficient used in representing $M'$ as a function of $u'^2 \delta_B$                                                                    | —                         |
| $\hat{M}'_{\delta S}$   | MYDSS   | 1       | Non-dimensional coefficient used in representing $M'$ as a function of $u'^2 \delta_S$                                                                    | —                         |
| $\hat{M}'_0$            | MYOS    | 1       | Non-dimensional coefficient used in representing $M'$ when angle of attack $\alpha$ , drift angle $\beta$ , manoeuvring device, and plane angles are zero | —                         |
| $\hat{M}'_{\theta}$     | MYOTHS  | 1       | Non-dimensional oscillatory coefficient about y-axis                                                                                                      | —                         |
| $m$                     | MA      | kg      | Model mass                                                                                                                                                | —                         |

**Table 1** (continued)

| Symbol                 | CC-code | SI-unit                 | Concept                                                |                                                                                                                                                                       |
|------------------------|---------|-------------------------|--------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                        |         |                         | Term                                                   | Definition or explanation                                                                                                                                             |
| N                      | MZ      | N m                     | Moment about z-axis                                    | Relative to ship-fixed axis system                                                                                                                                    |
| $N'_{\phi \text{dyn}}$ | DNDPDYS | rad <sup>-1</sup> a     | —                                                      | $\frac{\partial N'}{\partial \phi} \Big _{N'=\hat{N}'_0} - \frac{N_{\phi \text{stat}}}{\frac{\rho}{2} L^3 V^2}$                                                       |
| $N_{\phi \text{stat}}$ | DNDPST  | N m rad <sup>-1</sup> a | —                                                      | $\frac{\partial N}{\partial \phi} \Big _{V=0}$<br>from static test or calculation                                                                                     |
| $N'$                   | MZS     | 1                       | Non-dimensional moment about z-axis                    | Especially for submarines:<br>$\frac{N}{\frac{\rho}{2} L^3 V^2}$<br>where $N(u, v, w, p, q, r, \dot{v}, \dot{w}, \dot{p}, \dot{q}, \dot{r}, \phi, \theta)$            |
|                        |         |                         |                                                        | For surface ships only:<br>$\frac{N}{\frac{\rho}{2} L^3 V_0^2}$<br>where $N(V_0, \Delta u, v, w, p, q, r, \dot{v}, \dot{w}, \dot{p}, \dot{q}, \dot{r}, \phi, \theta)$ |
| $N'_{\text{in}}$       | MZINS   | 1                       | In-phase part of non-dimensional moment about z-axis   | $\frac{2}{nT} \int_t^{t+nT} N'(t) \sin \omega t \, dt$                                                                                                                |
| $N'_{\text{out}}$      | MZOUTS  | 1                       | Quadrature part of non-dimensional moment about z-axis | $\frac{2}{nT} \int_t^{t+nT} N'(t) \cos \omega t \, dt$                                                                                                                |
| $N'_p$                 | DNDPS   | 1                       | —                                                      | $\frac{\partial N'}{\partial p'} \Big _{N'=\hat{N}'_0}$                                                                                                               |
| $N'_{\dot{p}}$         | DNDPTS  | 1                       | —                                                      | $\frac{\partial N'}{\partial \dot{p}'} \Big _{N'=\hat{N}'_0}$                                                                                                         |
| $N'_{\ddot{p}}$        | DNDP3TS | 1                       | —                                                      | $\frac{\partial N'}{\partial \ddot{p}'} \Big _{N'=\hat{N}'_0}$                                                                                                        |
| $N'_{r'}$              | DNDRS   | 1                       | Slope through zero of $N'$ versus $r'$                 | $\frac{\partial N'}{\partial r'} \Big _{N'=\hat{N}'_0}$                                                                                                               |

Table 1 (continued)

| Symbol                        | CC-code | SI-unit | Concept                                                                                       |                                                               |
|-------------------------------|---------|---------|-----------------------------------------------------------------------------------------------|---------------------------------------------------------------|
|                               |         |         | Term                                                                                          | Definition or explanation                                     |
| $\dot{N}'_r$                  | DNDRTS  | 1       | —                                                                                             | $\frac{\partial N'}{\partial r'} \big _{N'=\dot{N}'_0}$       |
| $\dot{N}'_v$                  | DNDVS   | 1       | Slope through zero of $N'$ versus $v'$                                                        | $\frac{\partial N'}{\partial v'} \big _{N'=\dot{N}'_0}$       |
| $\dot{N}'_{\dot{v}}$          | DNDVTS  | 1       | —                                                                                             | $\frac{\partial N'}{\partial \dot{v}'} \big _{N'=\dot{N}'_0}$ |
| $\hat{N}'_{pq}$               | MZPQS   | 1       | Non-dimensional coefficient used in representing $N'$ as a function of $p' q'$                | —                                                             |
| $\hat{N}'_{qr}$               | MZQRS   | 1       | Non-dimensional coefficient used in representing $N'$ as a function of $q' r'$                | —                                                             |
| $\hat{N}'_r$                  | MZRS    | 1       | Non-dimensional coefficient used in representing $N'$ as a function of $F_{n0} r'$            | (for surface ships only)                                      |
| $\hat{N}'_{r r }$             | MZRRAS  | 1       | Non-dimensional coefficient used in representing $N'$ as a function of $r'  r' $              | —                                                             |
| $\hat{N}'_{r\delta\delta R}$  | MZRDDS  | 1       | Non-dimensional coefficient used in representing $N'$ as a function of $F_{n0} r' \delta_R^2$ | (for surface ships only)                                      |
| $\hat{N}'_{r \delta R}$       | MZRADS  | 1       | Non-dimensional coefficient used in representing $N'$ as a function of $F_{n0}  r'  \delta_R$ | (for surface ships only)                                      |
| $\hat{N}'_{ur}$               | MZURS   | 1       | Non-dimensional coefficient used in representing $N'$ as a function of $u' r'$                | (especially for submarines)                                   |
| $\hat{N}'_{ur\delta\delta R}$ | MZURDDS | 1       | Non-dimensional coefficient used in representing $N'$ as a function of $u' r' \delta_R^2$     | (especially for submarines)                                   |
| $\hat{N}'_{u r \delta R}$     | MZURADS | 1       | Non-dimensional coefficient used in representing $N'$ as a function of $u'  r'  \delta_R$     | (especially for submarines)                                   |
| $\hat{N}'_{uu}$               | MZUUS   | 1       | Non-dimensional coefficient used in representing $N'$ as a function of $u'^2$                 | (especially for submarines)                                   |
| $\hat{N}'_{uu\delta R}$       | MZUUDS  | 1       | Non-dimensional coefficient used in representing $N'$ as a function of $u'^2 \delta_R$        | (especially for submarines)                                   |
| $\hat{N}'_{uu\delta\delta R}$ | MZUUD3S | 1       | Non-dimensional coefficient used in representing $N'$ as a function of $u'^2 \delta_R^3$      | (especially for submarines)                                   |
| $\hat{N}'_{uv}$               | MZUVS   | 1       | Non-dimensional coefficient used in representing $N'$ as a function of $u' v'$                | (especially for submarines)                                   |

**Table 1** (continued)

| Symbol                              | CC-code | SI-unit | Concept                                                                                                                                                   |                           |
|-------------------------------------|---------|---------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------|
|                                     |         |         | Term                                                                                                                                                      | Definition or explanation |
| $\hat{N}'_v$                        | MZVS    | 1       | Non-dimensional coefficient used in representing $N'$ as a function of $v'$                                                                               | (for surface ships only)  |
| $\hat{N}'_{vq}$                     | MZVQS   | 1       | Non-dimensional coefficient used in representing $N'$ as a function of $v' q'$                                                                            | —                         |
| $\hat{N}'_{vrr}$                    | MZVRRS  | 1       | Non-dimensional coefficient used in representing $N'$ as a function of $F_{n0} v' r'^2$                                                                   | (for surface ships only)  |
| $\hat{N}'_{vvr}$                    | MZVVRs  | 1       | Non-dimensional coefficient used in representing $N'$ as a function of $F_{n0} v'^2 r'$                                                                   | (for surface ships only)  |
| $\hat{N}'_{vvv}$                    | MZV3S   | 1       | Non-dimensional coefficient used in representing $N'$ as a function of $v'^2 \sqrt{v'^2 + w'^2} F_{n0}$                                                   | (for surface ships only)  |
| $\hat{N}'_{v v }$                   | MZVVAS  | 1       | Non-dimensional coefficient used in representing $N'$ as a function of $v' \sqrt{v'^2 + w'^2}$                                                            | —                         |
| $\hat{N}'_{v r }$                   | MZVARS  | 1       | Non-dimensional coefficient used in representing $N'$ as a function of $r' \sqrt{v'^2 + w'^2}$                                                            | —                         |
| $\hat{N}'_{wp}$                     | MZWPS   | 1       | Non-dimensional coefficient used in representing $N'$ as a function of $w' p'$                                                                            | —                         |
| $\hat{N}'_{wr}$                     | MZWRS   | 1       | Non-dimensional coefficient used in representing $N'$ as a function of $w' r'$                                                                            | —                         |
| $\hat{N}'_{\Delta u}$               | MZDUS   | 1       | Non-dimensional coefficient used in representing $N'$ as a function of $\Delta u'$                                                                        | (for surface ships only)  |
| $\hat{N}'_{\Delta uv}$              | MZDUVS  | 1       | Non-dimensional coefficient used in representing $N'$ as a function of $\Delta u' v'$                                                                     | (for surface ships only)  |
| $\hat{N}'_{\Delta \Delta u}$        | MZDU2S  | 1       | Non-dimensional coefficient used in representing $N'$ as a function of $(\Delta u')^2$                                                                    | (for surface ships only)  |
| $\hat{N}'_{\delta R}$               | MZDRS   | 1       | Non-dimensional coefficient used in representing $N'$ as a function of $F_{n0}^2 \delta_R$                                                                | (for surface ships only)  |
| $\hat{N}'_{\delta \delta \delta R}$ | MZDR3S  | 1       | Non-dimensional coefficient used in representing $N'$ as a function of $F_{n0}^2 \delta_R^3$                                                              | (for surface ships only)  |
| $\hat{N}'_0$                        | MZ0S    | 1       | Non-dimensional coefficient used in representing $N'$ when angle of attack $\alpha$ , drift angle $\beta$ , manoeuvring device, and plane angles are zero | —                         |