CALMAR

CATENARY MOORING LINE CALCULATOR

TECHNICAL REFERENCES

1. TABLE OF CONTENTS

2. OBJECT OF PRESENT DOCUMENT

- Provide technical references of CALMAR, software calculating specifications for transitional catenary mooring lines for Aids to Navigation (AtoN) in its Release version 0.2.3.0.

3. DOCUMENTATION REFERENCES

[A] IALA Guideline No. 1066 "The Design of Floating Aid to Navigation Moorings"
IALA/AISM - Edition 1.1 (June 2010)

[B] "Recommendation E-107 On the Design of Normal Moorings"
IALA/AISM 1998 (withdrawn),

[C] "Position Mooring" - Offshore Standard
DNV-OS-E301 by Det Norske Veritas (October 2010)

[D] "Environmental Conditions and Environmental Loads"
Recommended Practice RP-C205 by Det Norske Veritas (October 2010)

[E] "Buoy Engineering " – by Henri O.BERTEAUX
Wiley-Interscience - JOHN WILEY & SONS (1976)

4. GENERAL CONSIDERATIONS

4.1 Scope of Calculations

4.1.1 Types of moorings lines

CALMAR calculates characteristics of transitional moorings in perfect catenary regime.

4.1.2 Definition of Catenary Regime

Catenary regime applies when "the mooring chain catenary meets the seabed tangentially exactly at the sinker when there are the maximum wind and tide (or current) loads on the buoy. The mooring loads will be transferred horizontally to the sinker which will be working as effectively as possible" [A].

4.1.3 Composition of moorings lines

CALMAR calculates only characteristics of moorings made of one homogeneous single type and size chain.
Composite moorings (made of different chain types or diameters with possible portions of other materials) cannot be calculated in the current version.

4.1.4 Mooring Sites conditions

CALMAR field of reliable calculations, in the actual version, excludes:
- Breaking waves conditions (alarm warning displayed in software - see 6.3.1)
- Environmental loads coming simultaneously from different directions,
- Taut or Slack regime moorings.

Users should also reasonably exclude calculations in following site conditions:
- Deep waters moorings (Depths > 200 m)
- High velocity currents (current velocity > 7 m/s)

4.1.5 Buoys Attitude

CALMAR, in the current version, does not account for buoy attitude (Trim, Roll and Yaw angles) and therefore the buoy axis is considered vertical.

4.1.6 Buoys Stability

CALMAR, in the current version, does not integrate Vertical Centres of Gravity and therefore does not account for buoy stability.

4.1.1 Drag Loads

CALMAR, in the current version, only takes into account the static horizontal components of drag loads.

5. LOADS CALCULATION

5.1 Surface Drags Loads in Water

5.1.1 Depth of Water

Calculations in CALMAR are always done for the highest level of Water defined by:
Depth (H) = (Nominal Depth + Tidal Range + (0.5 * Max. Wave Height) in meters.

5.1.2 Dynamic Pressure and Load Formula

All loads are calculated strictly according to IALA Guideline 1066 [A] as:

Drag Load = Dynamic Pressure * Exposed Area * Drag Coefficient / Acceleration of Gravity

with:

Pd (Dynamic Pressure) = 0.5 * (Medium Velocity ^ 2) * Medium Specific Gravity (Density)

where:

Drag Load	in	kg
Exposed Lateral Area	in	m^2
Acceleration of Gravity	in	m/s^2
Media Velocity	in	m/s
Density of media in	in	kg/m^3

5.1.3 Current Drag on Buoy

Current drag on buoy is calculated as:
Dynamic Pressure * Immersed Buoy and structure Lateral Area * Drag Coefficient
with:
Current speed = Total surface current speed as defined in 5.1.6.
Immersed Buoy Area = Lateral area of immersed portion of buoy and structure at computed draft.
In order to take into account the usual Surface Roughness and minimum fouling on buoys and buoy structures, a common drag coefficient of 1.2 is applied.

5.1.4 Surface Wind Generated Current

Speed of surface wind generated current (Vcw) is calculated as:
Vcw = 0.015 * Max Wind Speed (as given by site parameters)
according to Ref [C] & [D].

5.1.5 Wave Drag on Buoy

The wave drag on buoy and taken as an additional surface current speed due to wave particles velocity defined by Morison's load equations and taking in account Wave Significant Height and Wave Period, both given by site parameters. (see Ref [D]).

5.1.6 Surface Velocity Components

Total surface current speed is defined by adding its separate components:

	Speed of Tidal (or Stream) Current (as given by site parameters)
+	Speed of Surface Wind Generated Current (see 5.1.3)
+	Speed equivalent to Wave Drag (see 5.1.3)
=	Total Surface Current Speed

5.2 Drags Loads in Water

5.2.1 Current Drag on Chain

Current drag on buoy chain mooring line is calculated as:
Dynamic Pressure * Chain Area * Drag Coefficient with:
Chain Area = catenary height * 2.65 * chain nominal diameter (according to [C]).
Catenary Height = Depth (see 5.1.1) – calculated Depth of anchor ring under WL
Drag Coefficient = 1.2 to compensate for tangency factor of real catenary length.

5.2.2 Effect of Extensive Fouling

Considering usual regular maintenance schemes of AtoN services, an increase of buoy displacement and drag caused by extensive fouling (aged of more than two years) has not been taken into account. (see Ref [D]).

5.2.3 Effects of VIO & VIV

No Drag or Added Mass are taken into account for the effect of VIO (Vortex Induced Oscillations) or of VIV (Vortex Induced Vibrations) (see Ref [D]).

5.3 Drag Loads in Air

5.3.1 Wind Drag on Buoy

Wind drag on buoy is calculated as:
Dynamic Pressure * Emerged Buoy Area * Drag Coefficient with:
Wind speed = maximum wind speed as given by site parameters.
Emerged Buoy Area = Lateral area of emerged portion of buoy and structure at computed draft.
In order to take into account the usual surface roughness and minimum fouling on buoys and buoy structures, a common drag coefficient of 1.2 is applied.

5.3.2 Air Drag on Pylon and Top Mark

Wind drag on Pylon and Top Mark (Superstuctures) is calculated as:
Dynamic Pressure * Lateral Area of Pylon and Top Mark * Drag Coefficient with:
Wind speed = Maximum wind speed as given by site parameters.
Emerged Superstuctures Area = computed lateral areas of pylon and top mark.
In order to take into account the usual complex structure and construction of pylon and top mark, a common drag coefficient of 1.2 is applied.

6. CALCULATION PROCESS

6.1 Calculation Bases

All catenary characteristics, chain loads, sinker loads and specifications are calculated strictly according to IALA Guideline 1066 [A].

6.2 Main Calculation Steps

6.2.1 Calculation of Hydrostatic Table for Buoy

A table containing basic Hydrostatic Data (Drafts against Displaced Volume) is calculated at 1 mm increments from bottom of float to maximum displacement Drafts.
Input volumes are computed as they are defined in model definition.

6.2.2 Initial Buoy Draft Calculation

Initial buoy Displacement and Draft are calculated using declared total buoy mass and water at its specific gravity.

6.2.3 Initial Drag Loads Calculation

Initial drag load is calculated by addition of different drags:

6.2.3.1 Initial Current Drag on Buoy

Initial current drag on buoy is calculated at initial buoy draft following method described in 5.1.3.

6.2.3.2 Initial Current Drag on Chain

Initial current drag on Chain is calculated at initial buoy draft following method described in 5.2.1.

6.2.3.3 Initial Wind Drag Loads

Initial wind drag load on buoy and superstructures is calculated at initial buoy draft following method described in 5.3.

6.2.4 Initial Catenary Calculation

Initial catenary length is calculated using initial Drag Load (6.2.3), Depth (5.1.1) and chain parameters defined by user (A table of chain nominal diameters and mass per length for all chain types is built in the software).

6.2.5 Iterations for Equilibrium

Buoy displacement is then adjusted in iterations of steps 6.2.2, 6.2.3 and 6.2.4, adding weight of catenary required to cope with calculated loads and therefore increasing buoy displacement and drag loads, until the equilibrium solution between final drag loads, final necessary catenary lifted weight and final buoy displacement is achieved.

6.2.6 Calculation of Sinker Minimum Mass

Necessary mass of sinker to compensate for horizontal components of drags is calculated using sinker specific gravity defined by User, medium specific gravity, computed final necessary horizontal load, seabed internal friction angle and IALA recommended Safety Factor (1.5) to calculate minimum sinker mass.

6.3 Other Calculations

6.3.1 Breaking Wave Height

A breaking wave height (Hb) is calculated from User input parameters as:
Hb = (1.56 * (T ^ 2)) * 0.14 **If** Hm / (1.56 * (T ^ 2)) > 0.14 or **otherwise**:
Hb = (H * .78)
With:
T = Period of Maximum Height Waves in seconds
H = Maximum Water Depth on station (see 5.1.1)
A warning message is displayed if maximum wave height reaches breaking wave height and calculations are stopped (see 4.1.4).

7. CALCULATION PARAMETERS

7.1 Units

Defaults units used throughout CALMAR are SI Metric Units.
Flow velocities can be input in m/s (meter per second) or kn (knots)

7.2 Defaults Constant Values

Density of Air	ρa	129	kg/m³
Density of Water	ρw	1 025	kg/m³
Density of Cast Iron	ρci	7 320	kg/m³
Density of Steel	ρs	7 850	kg/m³
Steel Q1 tensile strength		430	N/mm²
Steel Q2 tensile strength		500	N/mm²
Steel Q3 tensile strength		690	N/mm²
Coef. Tensile Strength / Proof Load Studlink Chain		1.414	Coef
Coef. Tensile Strength / Proof Load 3D Chain		2	Coef
Coef. Tensile Strength / Proof Load 3.5D Chain		2	Coef
Coef. Tensile Strength / Proof Load 4D Chain		2	Coef
Coef. Tensile Strength / Proof Load 5D Chain		2	Coef
Coef. Tensile Strength / Proof Load 9D Chain		2	Coef
Seabed Internal Friction Angle		45	Degrees
Sinker Factor Of Safety	K	1.5	Coef
Coef. Max Wave Amplitude / Significant Height		1.85	Coef
Acceleration of Gravity	g	9.81	m/s²
Buoys Drag Coefficient in Water	Cdbw	1.2	Coef
Chains Drag Coefficient in Water	Cdcw	1.2	Coef
Buoys Drag Coefficient in Air	Cdba	1.2	Coef
Pylons Drag Coefficient in Air	Cdpa	1.2	Coef
TopMarks Drag Coefficient in Air	Cdta	1.2	Coef

8. RESULTS

8.1 Results in Result Screen Table:

8.1.1 Minimum Water Depth

Calculated as (Nominal Depth - (0.5 * Max.Wave Height)) in meters.

8.1.2 Maximum Water Depth see 5.1.1

8.1.3 Catenary Length

Minimum length of User specified chain to match horizontal drag in catenary regime.

8.1.4 Maximum Swinging Radius

Horizontal distance from sinker mooring eye to buoy's anchor ring under maximum mooring load.

8.1.5 Maximum Tension in Mooring

Maximum tension applied on mooring line by mooring loads.

8.1.6 Chain Safety Factor

Safety Factor of chain Proof Load divided by maximum tension on chain.
This factor ought to be > to 5 according to IALA Guideline 1066 [A].

8.1.7 Sinker Minimum Mass see 6.2.6

8.1.8 Horizontal Drag

Total of horizontal components of drag = horizontal component of maximum mooring line tension.

8.1.9 Buoy Reserve Buoyancy

Portion of total volume of buoy and structure left not used by buoy total displacement.

8.1.10 Buoy Total Displacement

Immersed weight of buoy = Weight of medium displaced by buoy immersed volume.

8.1.11 Buoy Free Board

Vertical distance from Loaded Water Line and top of float (without any trim angle).

8.1.12 Buoy Draft

Vertical distance from deepest part of buoy float or structure and Loaded Water Line (without any trim angle).

8.1.13 Immersed Lateral Plane

Lateral area of immersed buoy float or structure (without any trim angle) subjected to current drag loads.

8.1.14 Emerged Lateral Plane

Lateral area of total of emerged portions of buoy float or structure plus pylon plus top mark (without any trim angle) subjected to wind drag loads.

9. DOCUMENTATION

9.1 Acronyms

List of Acronyms used in present document:

AtoN	for	Aids to Navigation
CALM	for	Catenary Anchor Legs Mooring
Hs	for	Significant Wave Height
(o.e.)	for	Or Equivalent
SPM	for	Single Point Mooring
VIO	for	Vortex Induced Oscillations
VIV	for	Vortex Induced Vibrations
WL	for	Water Line

10. GENERAL NOTES

10.1 Possible Future developments

Following new functions could be added to present version of CALMAR:

- Input of different media Specific Gravity variable,
- Addition of supplementary languages,
- Addition of supplementary chains characteristics,
- Input of seabed internal friction angle variable,
- Calculation of composites moorings,
- Calculation in breaking waves,
- Attitude (trim) of buoy under drag loads,
- Different mooring points variable,
- Approaches on dynamic characteristics,
- Calculation in Ice.

11. LIST of ANNEXES

No Annex.

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