UNIVERSIDADE DA CORUÑA

Escola Politécnica Superior

Trabajo Fin de Máster
CURSO 2016/2017

BUQUE LNG DE MEMBRANA DE 145.000 m³

Máster en Ingeniería Naval y Oceánica

ALUMNA/O

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TUTORAS/ES

Vicente Díaz Casas

FECHA

SEPTIEMBRE DE 2017

CUADERNO 6

En el presente cuaderno realizaremos el cálculo de la potencia propulsiva del buque, escogeremos un propulsor y definiremos sus características. También diseñaremos el timón y calcularemos la potencia del servo.

Escola Politécnica Superior

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BUQUE LNG DE MEMBRANA DE 145.000 m³

Máster en Ingeniería Naval y Oceánica

CUADERNO 6

PREDICCIÓN DE POTENCIA Y DISEÑO DE PROPULSORES Y TIMONES

Escola Politécnica Superior

UNIVERSIDADE DA CORUÑA

DEPARTAMENTO DE INGENIERÍA NAVAL Y OCEÁNICA

TRABAJO FIN DE MÁSTER

CURSO 2016-2017

PROYECTO NÚMERO: 17-32 P

TIPO DE BUQUE: Buque tanque LNG de membrana

CLASIFICACIÓN, COTA Y REGLAMENTOS DE APLICACIÓN: DNV, SOLAS, MARPOL, CIG.

CARACTERÍSTICAS DE LA CARGA: gas natural licuado con capacidad para 145.000 m^3.

VELOCIDAD Y AUTONOMÍA: 19,5 nudos a la velocidad de servicio, 85% MCR + 15% MM. 12.000 millas a la velocidad de servicio.

SISTEMAS Y EQUIPOS DE CARGA / DESCARGA: los habituales en este tipo de buque.

PROPULSIÓN: Propulsión Diesel eléctrico. Dos líneas de ejes

TRIPULACIÓN Y PASAJE: 35 tripulantes en camarotes individuales.

OTROS EQUIPOS E INSTALACIONES: Las habituales en este tipo de buque.

Ferrol, Abril de 2017

ALUMNO: D. Ismael Grandal Mouriz

ÍNDICE:

1-INTRODUCCIÓN

En el presente cuaderno vamos a realizar una estimación de la potencia propulsora de nuestro buque y seleccionaremos un propulsor. También vamos a indicar las características del timón y de la hélice.

Las características principales del buque proyecto son las siguientes:

L	269,7
B	43,2
D	26,3
T	11,5
Volumen	145.000
Δ	105.379
V	19,5
Fn	0,1950
Cb	0,7673
Cm	0,9971
Cp	0,7905

2-CÁLCULO DE LA POTENCIA PROPULSORA

Con las características fijadas en las RPA tenemos:

-Velocidad de 19,5 nudos en régimen de servicio al 85 %

-15 % de margen de mar

Para hacer una estimación de esta potencia vamos a utilizar el software NAVCAD.

Utilizaremos los criterios de Holtrop y de Keller.

Los límites de aplicación de Holtrop se muestran en la siguiente tabla y se ajustan a las características de nuestro buque:

PARÁMETRO	MÍNIMO	MÁXIMO	BUQUE PROYECTO
Fn	0,0000	0,8500	0,1950
Cp	0,5500	0,8500	0,7905
Lpp/B	3,9000	9,5000	6,2431

Cálculo teórico

El proceso de cálculo teórico de la potencia es el que se muestra a continuación:

1. Cálculo de la resistencia al avance (R_T)

2. Cálculo de la potencia efectiva (EHP)

$$EHP = \frac{R_T \cdot V}{75}$$

Donde:

V: velocidad del buque.

3. Cálculo de la potencia al freno (BHP)

$$BHP = \frac{EHP}{\eta_P}$$

Donde:

η_p: rendimiento total de propulsión

$$\eta_P = \eta_h \cdot \eta_0 \cdot \eta_{rr} \cdot \eta_m$$

Donde:

η_h: rendimiento del casco

$$\eta_h = \frac{1 - t}{1 - w}$$

Donde:

t: coeficiente de succión

w: coeficiente de estela

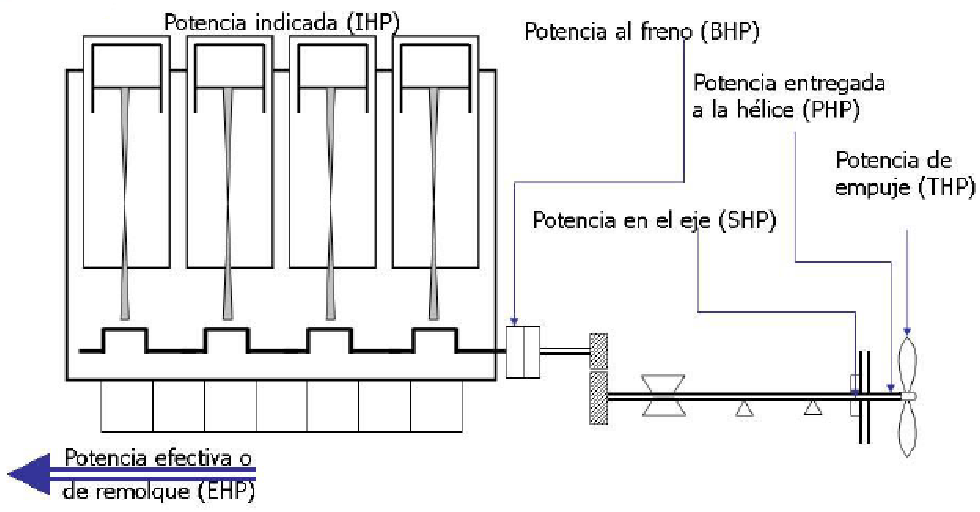
η_0: rendimiento del propulsor en aguas libres

η_{rr}: rendimiento rotativo-relativo

"Aclaración": el producto de los tres rendimientos anteriores se conoce como rendimiento cuasipropulsivo, y depende únicamente de factores hidrodinámicos.

η_m: rendimiento mecánico. El rendimiento mecánico de la máquina incluye las pérdidas por rozamiento en los cilindros, bielas y cigüeñal.

Hemos calculado solamente EHP y BHP, que son las que nos interesan. En la siguiente imagen podemos ver un esquema con las distintas potencias en cada punto.



Cálculo de la resistencia al avance (R_T) y de la potencia efectiva (EHP)

Vamos a proceder a calcular la resistencia al avance (R_T) la potencia efectiva (EHP). Para ello nos serviremos del software NAVCAD.

Algunos de los datos de entrada a NAVCAD los calcula directamente el programa y otros los introducimos con los datos obtenidos de Maxsurf. Se pueden ver en los anexos, pero algunos son los siguientes:

Eslora en la flotación

L_{WL} = 275,945 m.

Bulbo de proa

Altura (h)

h= 7,49 m.

Protuberancia (x)

x = 8,76 m.

Superficie mojada

S = 14.716,7 m^2

Centro de carena

LCB = 133,199 m.

Centro de gravedad de la flotación

LCF = 125,596 m.

Área del plano de la flotación

Waterplane Area = 9.937,3 m^2

Área de la sección máxima (maestra)

Max. Section Area = 490,4 m^2

Semiángulo de entrada de la flotación

Se obtiene del plano de formas, y es igual a 27º.

Diámetro máximo del propulsor

Hemos analizado las dimensiones de los propulsores de nuestros buques de la base de datos, incluido nuestro buque base. El diámetro de los propulsores oscila entre 7,8 y 9 metros. Para el caso de nuestro buque base (Barcelona Knutsen), el diámetro es de 7,8 m. Hemos decidido escoger como diámetro máximo 8 m.

Número de propulsores: 2

Otros datos de entrada son:

Densidad del agua: 1,025 t/m^3

Viscosidad cinemática: $1{,}18830 \cdot 10^{-6}$ m^2/s

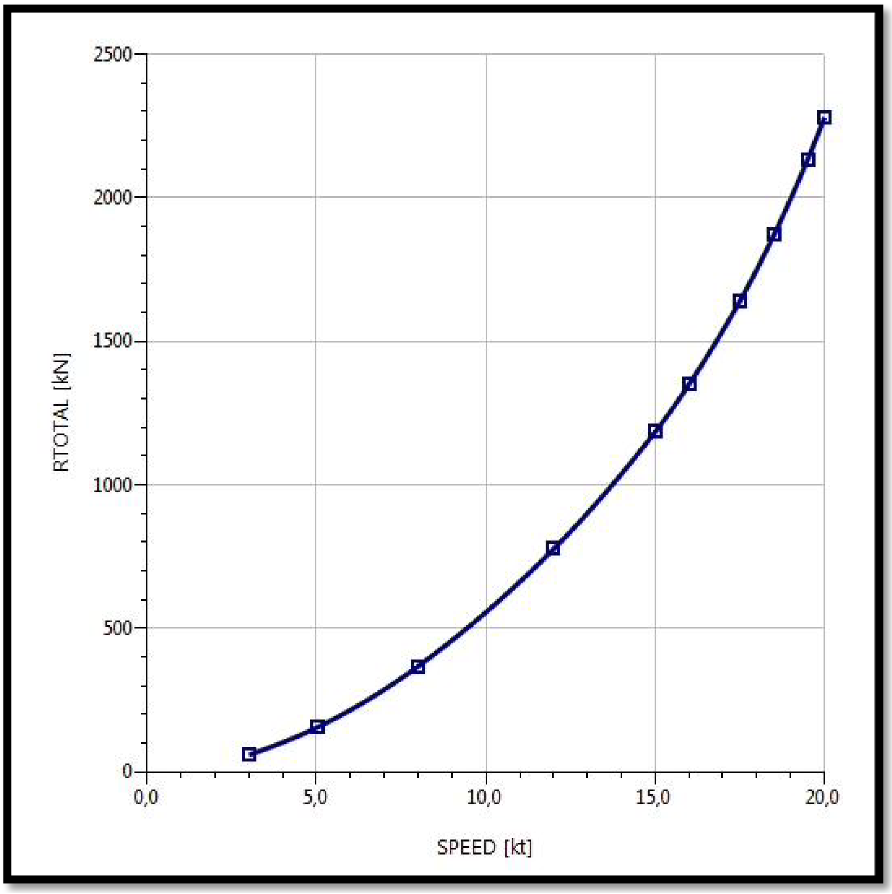
Margen de diseño: 15 %.

El programa nos ofrece los siguientes resultados

:

VELOCIDAD (knot)	**RT (kN)**	**EHP (kW)**
19,5	2.132,64	21.393,9

En la siguiente imagen vemos la gráfica de la resistencia al avance en función de la velocidad:



Cálculo de la potencia al freno (BHP)

En este apartado calcularemos la potencia al freno, potencia necesaria del buque para la propulsión en condiciones de servicio según nuestras RPA.

Introducimos en NAVCAD los mismos datos que en el apartado anterior, así como otros (como la inmersión del eje) que podemos ver en los anexos.

Destacar que hacemos el cálculo con un predictivo con un propulsor de 4 palas. Cuando tengamos la potencia, seleccionaremos el que mejor rendimiento nos ofrezca en relación a la potencia.

Para calcular las dimensiones del propulsor (que serán estimadas), tenemos que jugar con fijar algunas dimensiones estimadas (como las rpm, el diámetro máximo o la relación de reducción) y que nos las calcule y luego a la inversa, puesto que el programa, con nuestras características y una velocidad de 19,5 nudos, si queremos calcular todas nuestras características sin fijar ninguna, colapsa.

El cálculo de la potencia se hará por empuje, ya que desconocemos nuestra potencia.

La BHP o PB nos la da directamente el programa, que nos arroja como resultado incluidos rendimientos y margen de mar:

VELOCIDAD	**BHP (KkW)**
19,5	34.946,7

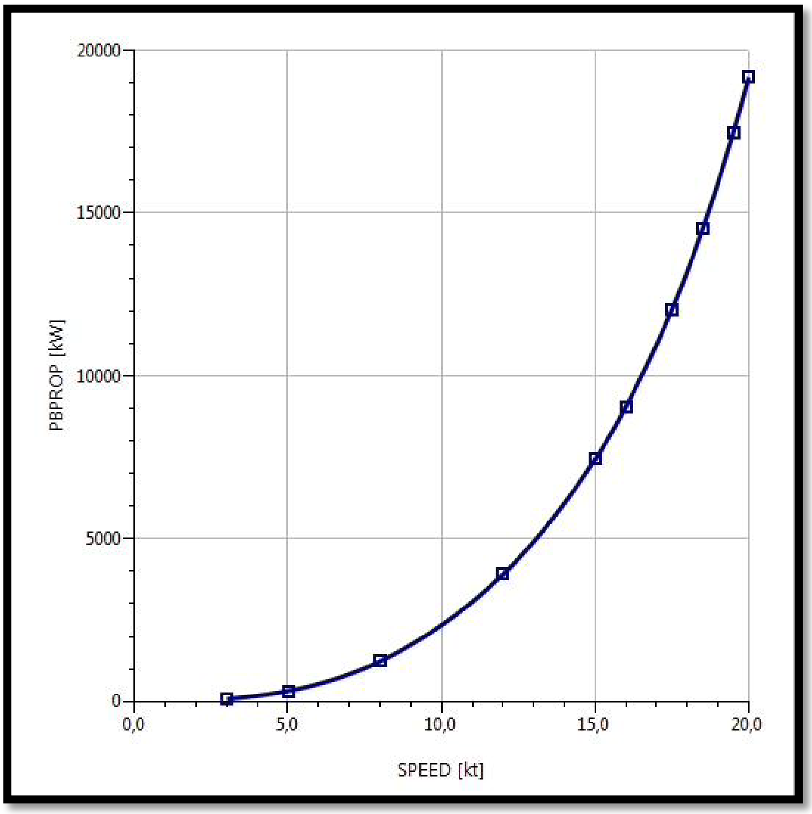
Tendremos por tanto que nuestra BHP final será:

$$BHP_{FINAL} = \frac{BHP}{RM} = 41.114\ kW$$

Donde:

RM: régimen del motor (0,85, o lo que es lo mismo, 85 %).

En la siguiente imagen se muestra una gráfica de la potencia demandada para distintas velocidades.



3-SELECCIÓN DEL MOTOR

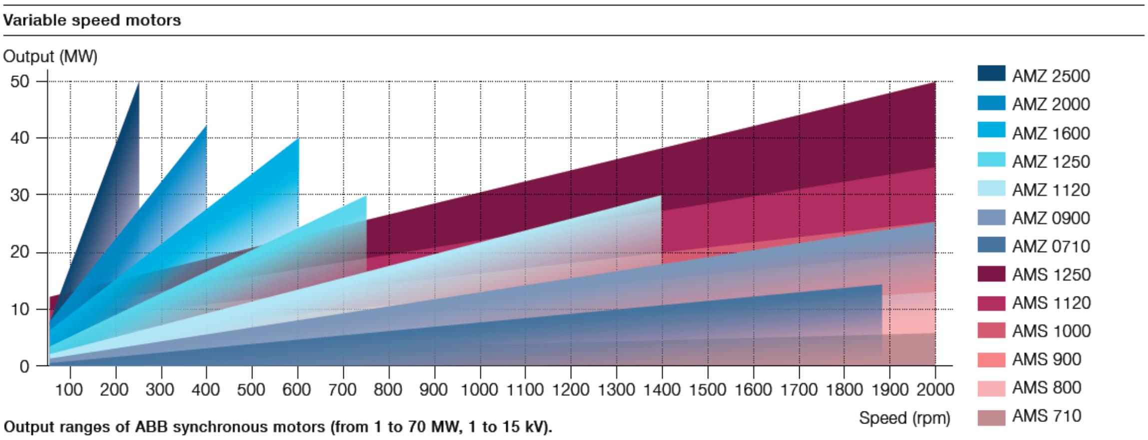
La propulsión del buque es eléctrica (viene definida por nuestras RPA, en el cuaderno 1 ya hicimos una breve descripción de sus ventajas), lo que significa que son motores eléctricos los que generan el movimiento de las hélices. Los motores duales (diesel-gas) que debe llevar el buque instalados no son propulsores sino generadores. Se encargan de generar la energía eléctrica suficiente para alimentar a los motores eléctricos y demás consumidores del buque.

Motores propulsores

Los motores propulsores se determinan con la potencia al freno calculada anteriormente.

El buque dispone de dos líneas de ejes con dos hélices. Cada una de las hélices estará accionada por un motor eléctrico.

Consultamos el catálogo oficial del fabricante ABB y decidimos instalar a bordo dos motores eléctricos síncronos AMZ 1250 de velocidad variable.



Output ranges of ABB synchronous motors (from 1 to 70 MW, 1 to 15 kV).

El motor AMZ 1250 genera a una velocidad (rpm) de 740 rpm, 30 MW de potencia, y a 600 rpm, aproximadamente 22 MW. Este es el motor que más se ajusta a la potencia que necesitamos para la propulsión.

Motores generadores

Para los motores generadores llevaremos dos del tipo 18V50 y otros dos del tipo 16V50 de Wärtisilä para satisfacer nuestra demanda de potencia.

Justificaremos esta elección y analizaremos los motores y las demandas de potencia en los cuadernos 10 y 11.

4-CÁLCULO Y SELECCIÓN DEL PROPULSOR

Una vez que tenemos nuestra BHP real (44.000 kW) y 600 rpm, introducimos estos valores en NAVCAD y calculamos nuestro propulsor.

Vamos a calcular propulsores de 4,5 y 6 palas. De esta manera podremos escoger el que nos ofrece mayor rendimiento y nos demanda menos potencia.

En la siguiente tabla podemos ver un resumen con las características de cada uno de los propulsores calculados.

Propulsor	Relac. Reducc	Diámetro	Paso	RPM	η	BHP requerida	% cavitación
4 palas	7,5	8 m.	6,65 m.	98	0,6258	35.245 kW	2
5 palas	7,5	8 m.	6,72 m.	97	0,6186	35.653,6 kW	2
6 palas	7,5	8 m.	6,72 m.	96	0,6015	36.668,8 kW	2

El propulsor que menos potencia nos demanda y que mejor rendimiento nos ofrece, es el de 4 palas, por lo que es el que escogeremos para las dos líneas de ejes de nuestro buque. También podemos ver sus características así como sus formas en los reports y plano anexados.

Evidentemente, nuestro motor irá acoplado por medio de engranajes a una reductora, puesto que al ser un motor eléctrico, tiene revoluciones sustancialmente más altas que las que precisa el propulsor, como vemos en la relación de reducción.

5-CLARAS DEL PROPULSOR

Nos regiremos, como indican nuestras RPA, por la Sociedad de Clasificación DET NORSKE VERITAS

Table C1 Minimum clearances

For single screw ships:	*For twin screw ships:*
a ≥ 0.2 R (m)	
b ≥ (0.7 – 0.04 Z_p) R (m)	
c ≥ (0.48 – 0.02 Z_p) R (m)	c ≥ (0.6 – 0.02 Z_p) R (m)
e ≥ 0.07 R (m)	

R = propeller radius in m
Z_p = number of propeller blades.

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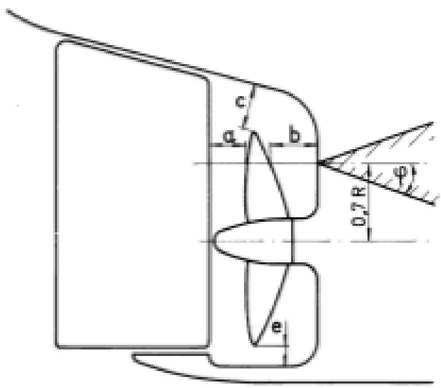


Fig. 2
Propeller clearances

Las claras mínimas exigidas entre el propulsor y el codaste son:

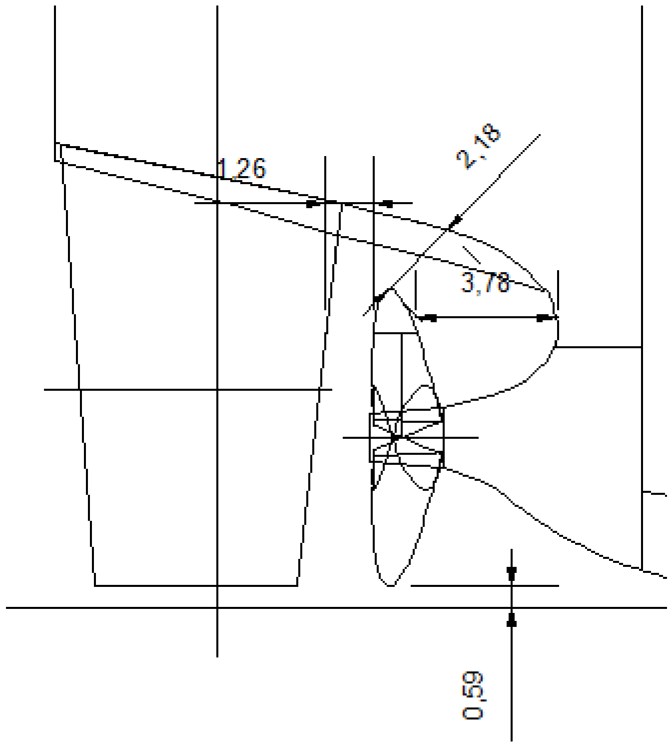
Clara a: a ≥ 0,2·R = 0,85

Clara b: b ≥ (0,7-0,04Z)·R = 2,16

Clara c: c ≥ (0,6-0,02Z)·R = 2,08

Clara e: e ≥ 0,07·R = 0,28

Donde el radio de la hélice es 4 (cuaderno 6) y Z el número de palas, igual a 4 (cuaderno 6).



En el esquema vemos las claras a (1,26), b (3,78), c (2,18) y e (0,59). Cumplen con las exigencias mínimas en todos los casos.

6-DISEÑO DEL TIMÓN

La normativa utilizada para el diseño del timón la obtenemos del DNV (Parte 3, Capítulo 3, Sección 2). De ahí sacamos la formulación y se adjunta en los anexos.

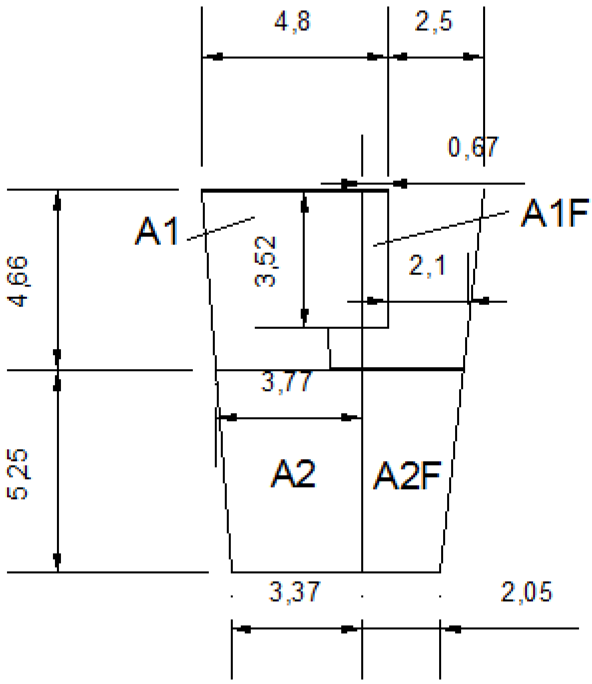
Nuestro timón será similar al del buque base, de tipo semisuspendido.

Área de la pala

Utilizamos la normativa del DNV para equipos y seguridad (Parte 3 Capítulo 3 C105) para estimar el área del timón:

$$A = \frac{T \cdot L}{100} \cdot \left[1 + 50 \cdot {C_B}^2 \cdot \left(\frac{B}{L}\right)^2\right] = 54{,}44\ m^2$$

Dividimos el timón en cuatro zonas, teniendo como referencia nuestro buque base, como se muestra en el croquis con las cotas de la siguiente imagen:



Calculando las áreas tenemos que:

A1	17,2830
A2	18,9675
A1F	2,6845
A2F	15,9732
ATOTAL	54,9082

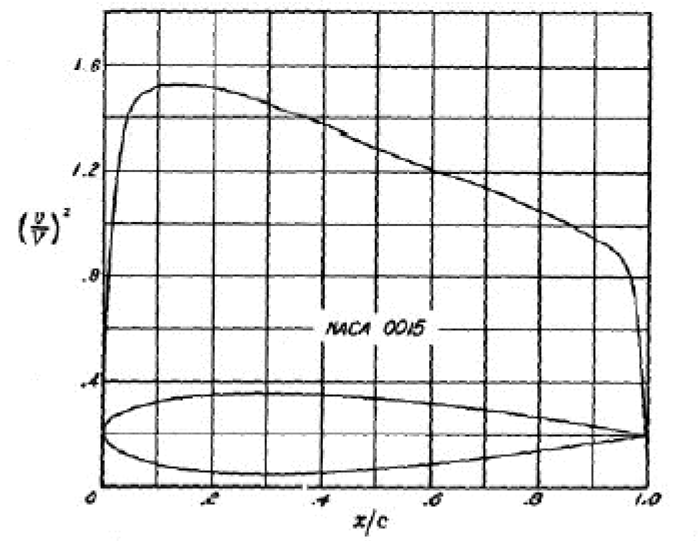
Por lo que vemos que tenemos un área de 54,9082 m², ligeramente superior a la mínima que hemos calculado por la fórmula del DNV.

Perfil del timón

Para el tipo de perfil del timón seleccionamos un perfil NACA que responde a la siguiente relación:

$$x \cdot y = \frac{t}{c}$$

THEORY OF WING SECTIONS



x (per cent c)	y (per cent c)	$(v/V)^2$	v/V	$\Delta v_a/V$
0	0	0	0	1.600
0.5	.....	0.546	0.739	1.312
1.25	2.367	0.933	0.966	1.112
2.5	3.268	1.237	1.112	0.900
5.0	4.443	1.450	1.204	0.675
7.5	5.250	1.498	1.224	0.557
10	5.853	1.520	1.233	0.479
15	6.682	1.520	1.233	0.381
20	7.172	1.510	1.220	0.320
25	7.427	1.484	1.218	0.274
30	7.502	1.450	1.204	0.239
40	7.254	1.369	1.170	0.185
50	6.617	1.279	1.131	0.146
60	5.704	1.206	1.098	0.115
70	4.580	1.132	1.064	0.090
80	3.279	1.049	1.024	0.065
90	1.810	0.945	0.972	0.041
95	1.008	0.872	0.934	0.027
100	0.158	0	0	0
L.E. radius: 2.48 per cent c				

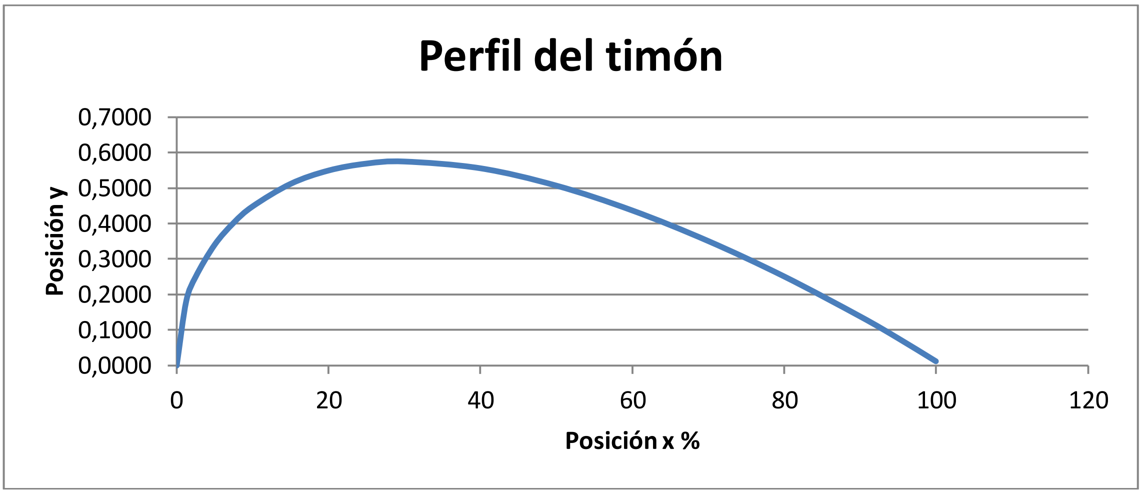
NACA 0015 Basic Thickness Form

Para el cálculo del perfil de los timones de nuestro buque nos basaremos en la tabla anterior. Teniendo en cuenta la longitud del timón (7,66 m.), obtenemos:

$$y = a \cdot \frac{l}{100}$$

Para nuestro caso, tenemos:

x	a	y
0	0	0,0000
1,25	2,367	0,1813
2,5	3,268	0,2503
5	4,443	0,3403
7,5	5,25	0,4022
10	5,853	0,4483
15	6,682	0,5118
20	7,172	0,5494
25	7,427	0,5689
30	7,502	0,5747
40	7,254	0,5557
50	6,617	0,5069
60	5,704	0,4369
70	4,58	0,3508
80	3,279	0,2512
90	1,81	0,1386
95	1,008	0,0772
100	0,158	0,0121



7-CÁLCULO DE LA POTENCIA DEL SERVO

A continuación procedemos a calcular la potencia del servo

$$P = M \cdot \frac{2 \cdot \pi \cdot \theta \cdot 1}{360 \cdot t \cdot \eta} = 152{,}19\ kW$$

Donde:

P: potencia del servomotor en kW

M: par máximo (kNm). El mayor par torsor es ciando, como calculamos más abajo.

θ: ángulo de giro (65°)

t: tiempo para efectuar el giro (28 s)

η: rendimiento mecánico del servomotor (0,8)

Hay que determinar el par máximo:

$$M_{TR} = F \cdot x_e$$

$$M_{TR}(avante) = 778{,}52\ kNm$$

$$M_{TR}(ciando) = 3005{,}06\ kNm$$

Donde:

F: fuerza lateral ejercida sobre el timón en kN

Xe: centro de empuje (m)

Calculamos F y xe:

$$F = 0{,}044 \cdot k_1 \cdot k_2 \cdot k_3 \cdot A \cdot V^2$$

$$F_{avante} = 4042{,}14\ kN$$

$$F_{ciando} = 1306{,}55\ kN$$

Donde:

A: área del timón (54,9082 m²)

V: velocidad del buque (19,5 knot)

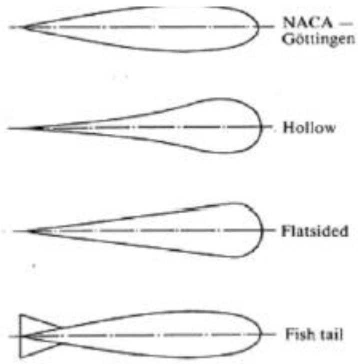
V (ciando) = 2/3 V = 13 knot

K1: coeficiente dependiente del perfil del timón

Table D1 Rudder profile type - coefficient

Profile type	*Ahead*	*Astern*
NACA - Göttingen	1.1	0.8
Hollow profile [1]	1.35	0.9
Flatsided	1.1	0.9
Profile with «fish tail»	1.4	0.8
Rudder with flap	1.65	1.3
Nozzle rudder	1.9	1.5

1) Profile where the width somewhere along the length is 75% or less of the width of a flat side profile with same nose radius and a straight line tangent to after end



Rudder profiles.

-Avante: 1,1

-Ciando: 0,8

K2: coeficiente dependiente de la disposición del timón (en nuestro caso 1)

K3: (máximo 4)

$$k_3 = \frac{H^2}{A} + 2 = 4{,}54 \rightarrow \ cogemos\ 4$$

Donde:

H: altura media del timón (11,81 m)

A: área del timón (54,9082 m²)

Calculamos xe:

$$x_e = B \cdot \left(\alpha - \frac{A_F}{A}\right)$$

$$x_e\ (avante) = 0{,}1926\ m.$$

$$x_e(ciando) = 2{,}30\ m.$$

Donde:

B: eslora media del timón (6,4119 m.)

α: 0,33 (avante) y 0,66 (ciando)

AF: Área del timón situada a proa del eje del timón (16,47 m²)

8-BIBLIOGRAFÍA

-"El Proyecto Básico del Buque Mercante"; Ricardo Alvariño, Juan José Azpíroz y Manuel Meizoso.

-"Proyectos de Buques y Artefactos", Fernando Junco Ocampo.

-Apuntes asignatura "Métodos Computacionales Aplicados al Proyecto del Buque", EPS Ferrol.

-Reglamento Sociedad de Clasificación DNV.

-Diverso material web.

ANEXO I

Normativa DNV

less than 65 Brinell. 13% Chromium steel shall be avoided.

302 Synthetic bearing bushing materials shall be of an approved type. For this type of bushing, adequate supply of lubrication to the bearing for cooling/lubrication purposes shall be provided.

303 The maximum surface pressure p_m for the various bearing combinations shall be taken as given in Table B2. Higher values than given in Table B2 may be taken in accordance with the maker's specification if they are verified by tests.

(IACS UR S10)

Table B2 Bearing surface pressures	
Bearing material	*p_m (kN/m²)*
Lignum vitae	2 500
White metal, oil lubricated	4 500
Synthetic material with hardness between 60 and 70 Shore D 1)	5 500
Steel 2) and bronze and hot-pressed bronze-graphite materials	7 000
1) Indentation hardness test at 23°C and with 50% moisture, according to a recognized standard	
2) Stainless and wear-resistant steel in an approved combination with stock liner	

B 400 Material certificates

401 «Det Norske Veritas Product Certificate» (NV) will be required for:

— sternframe structural parts
— rudder structural parts
— rudder shaft or pintles
— rudder stock
— rudder carrier.

402 "Works certificate" (W) will be accepted for:

— bolts
— stoppers.

B 500 Heat treatment

501 Nodular cast iron and cast steel parts for transmission of rudder torque by means of conical connections shall be stress relieved.

C. Arrangement and Details

C 100 Sternframes and rudders

101 Relevant types of rudder arrangements are shown in Fig.1. Other combinations of couplings and bearings may be applied.

102 Suitable arrangement to prevent the rudder from lifting and accidental unshipping shall be provided. The arrangement shall effectively limit vertical movement of rudder in case of extreme (accidental) vertical load on rudder.

103 Effective means shall be provided for supporting the weight of the rudder without excessive bearing pressure, e.g. by a rudder carrier attached to the upper part of the rudder stock. The hull structure in way of the rudder carrier shall be suitably strengthened.

104 If the rudder trunk is open to the sea, a seal or stuffing box shall be fitted above the deepest load waterline, to prevent water from entering the steering gear compartment and the lubricant from being washed away from the rudder carrier.

An additional seal of approved type is required when the rudder carrier is below the summer load waterline.

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Guidance note:

The after body should be so shaped as to ensure a proper flow of water to the propeller, and so as to prevent uneven formation of eddies as far as possible. The apex of the waterlines in front of the propeller should have the least possible radius, together with a relatively small angle ϕ. Plane or approximately plane parts above the propeller tip should be avoided.

The strength of pressure impulses from propeller to hull will normally decrease with increasing clearances. However, even with large clearances to the propeller, a hull may be exposed to strong impulses if the propeller is subject to heavy cavitation.

For a moderately cavitating propeller, the following minimum clearances are proposed (see Table C1 and Fig.2):

Table C1 Minimum clearances	
For single screw ships:	*For twin screw ships:*
$a \geq 0.2$ R (m)	
$b \geq (0.7 - 0.04\ Z_P)$ R (m)	
$c \geq (0.48 - 0.02\ Z_P)$ R (m)	$c \geq (0.6 - 0.02\ Z_P)$ R (m)
$e \geq 0.07$ R (m)	

R = propeller radius in m
Z_P = number of propeller blades.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

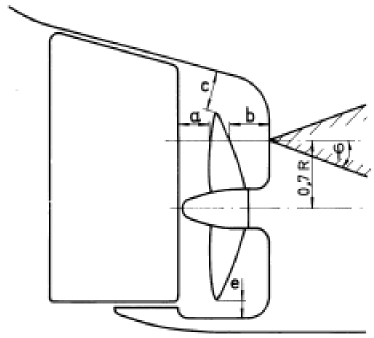

Fig. 2
Propeller clearances

106

Guidance note:

Rudders (one or more) working directly behind a propeller should preferably have a total area not less than:

$$A = \frac{TL}{100}\left[1 + 50C_B^{\ 2}\left(\frac{B}{L}\right)^2\right] \quad (m^2)$$

For ships which frequently manoeuvre in harbours, canals or other narrow waters, the rudder area determined by the formula should be increased. For ships with a streamlined rudder post, half of the lateral area of the post may be included in the rudder area. For ships with a rudder horn, the whole area of the horn laying below a horizontal line from the top of the rudder may be included.

Rudders not working directly behind a propeller should have the area as given above, increased by at least 30%.

Rudders with special profiles or special configurations (e.g. flaps or nozzles) giving increased efficiency may have smaller total areas.

For ships with large freeboard and/or high continuous superstructures an increase of the rudder area ought to be considered.

Larger rudder area may result in excessive heeling angle when using the rudder in extreme position at full speed ahead. This is particularly relevant for passenger vessels, ferries, vehicle ro/ro carriers and other vessels where the combination of speed, draught, vertical centre of gravity and metacentric height may result in excessive heeling angle in case of smaller turning circles. For estimating the result angle of heel, reference is made to Pt.5 Ch.2 Sec.2 F300.

In cases where the resulting angle of heel may exceed 10 degrees, the Master should be provided with warning about this in the stability manual.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

107

Guidance note:

In order to minimise vibrations, the balancing and design of the rudders should be carried out as follows:

- the balanced portion should not be greater than 23% of the total area of the rudder
- the length of the balanced part at any horizontal section should nowhere be greater than 35% of the total length of the rudder
- the widest part of the rudder section should preferably be at least 30% aft of the leading edge of the rudder section considered.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

108 Over-balanced rudders are subject to special consideration with respect to type of steering gear and risk of an unexpected and uncontrolled sudden large movement of rudder causing severe change of ship's pre-set course. See Pt.4 Ch.14 Sec.1 B900.

Guidance note:

A rudder shall be considered over-balanced, when balanced portion exceed 30% in any actual load condition. Special rudder types, such as flap rudders, are subject to special consideration.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

D. Design Loads and Stress Analysis

D 100 Rudder force and rudder torque, general

101 The rudder force upon which the rudder scantlings shall be based shall be determined from the following formula:

$$F_R = 0.044\, k_1\, k_2\, k_3\, A\, V^2 \quad \text{(kN)}$$

A = area of rudder blade in m^2, including area of flap.
= vertical projected area of nozzle rudder
k_1 = coefficient depending on rudder profile type (see Fig.3):

Table D1 Rudder profile type - coefficient

Profile type	*Ahead*	*Astern*
NACA - Göttingen	1.1	0.8
Hollow profile [1]	1.35	0.9
Flatsided	1.1	0.9
Profile with «fish tail»	1.4	0.8
Rudder with flap	1.65	1.3
Nozzle rudder	1.9	1.5

1) Profile where the width somewhere along the length is 75% or less of the width of a flat side profile with same nose radius and a straight line tangent to after end

k_2 = coefficient depending on rudder/nozzle arrangement
= 1.0 in general
= 0.8 for rudders which at no angle of helm work in the propeller slip stream
= 1.15 for rudders behind a fixed propeller nozzle

$k_3 = \dfrac{H^2}{A_t} + 2$ not to be taken greater than 4

H = mean height in m of the rudder area. Mean height and mean breadth B of rudder area to be calculated as shown in Fig.4
A_t = total area of rudder blade in m^2 including area of flap and area of rudder post or rudder horn, if any, within the height H.
V = maximum service speed (knots) with the ship on summer load waterline. When the speed is less than 10 knots, V shall be replaced by the expression:

$$V_{min} = \frac{V + 20}{3}$$

For the astern condition the maximum astern speed shall be used, however, in no case less than:

$$V_{astern} = 0.5\, V$$

The maximum service speed corresponds to the maximum continuous rating (MCR) of the engine. In special ship types (such as tugs) the maximum output of the propelling machinery may exceed MCR by more than 15%. In such cases V shall be increased by the following percentage:

Table D2 Percentage increase in MCR vs V

Maximum engine output above normal (%)	*15*	*20*	*25*	*30*	*35*	*40*
V increase (%)	3	5	7	9	11	12

102 The rule rudder torque shall be calculated for both the ahead and astern condition according to the formula:

$$M_{TR} = F_R\, x_e \quad \text{(kNm)}$$
$$= \text{minimum } 0.1\, F_R\, B$$

F_R = as given in 101 for ahead and astern conditions
x_e = $B\,(\alpha - k)$ (m)
B = mean breadth of rudder area, see Fig.4
α = 0.33 for ahead condition
= 0.66 for astern condition
$k = \dfrac{A_F}{A}$
A_F = area in m^2 of the portion of the rudder blade area situated ahead of the center line of the rudder stock
A = rudder blade area as given in 101.

For special rudder designs (such as flap rudders) direct calculations of rudder torque, supported by measurements on similar rudders, may be considered as basis for rudder torque estimation.

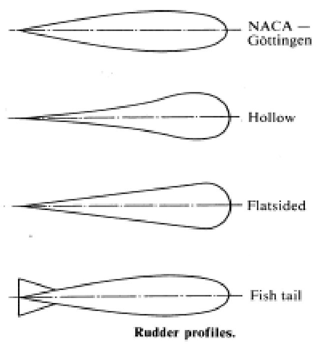

Fig. 3
Rudder profiles

D 200 Rudders with stepped contours

201 The total rudder force F_R shall be calculated according to 101, with height and area taken for the whole rudder.

202 The pressure distribution over the rudder area may be determined by dividing the rudder into relevant rectangular or trapezoidal areas, see e.g. Fig.5. The rule rudder torque may be determined by:

$$M_{TR} = \sum_{i=1}^{n} (F_{Ri} x_{ei}) \quad \text{(kNm)}$$

$$= \text{minimum } 0.1\, F_R\, x_{em}$$

n = number of parts
i = integer

$$F_{Ri} = \frac{A_i}{A} F_R$$

$$x_{ei} = B_i (\alpha - k_i)$$

$$x_{em} = \sum_{i=1}^{n} \frac{(A_i B_i)}{A}$$

A_i = partial area in m^2
B_i = mean breadth of part area, see Fig.4
α = as given in 102

For parts of a rudder behind a fixed structure such as a rudder horn:

α = 0.25 for ahead condition
= 0.55 for astern condition

$$k_i = \frac{A_{iF}}{A_i}$$

A_{iF} = rudder part area forward of rudder stock centre line, see Fig.5

F_R and A as given in 101.

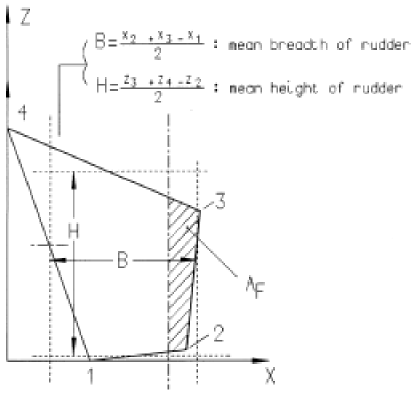

Fig. 4
Rudder dimensions

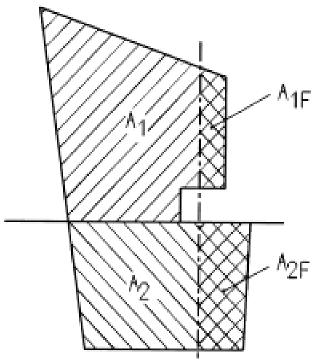

Fig. 5
Rudder area distribution

D 300 Stress analysis

301 The rudder force and resulting rudder torque as given in 100 and 200, causes bending moments and shear forces in the rudder body, bending moments and torques in the rudder stock, supporting forces in pintle bearings and rudder stock bearings and bending moments, shear forces and torques in rudder horns and heel pieces.

The bending moments, shear forces and torques as well as the reaction forces shall be determined by a direct calculation or by approximate simplified formulae as given in the following.

For rudders supported by sole pieces or rudder horns these structures shall be included in the calculation model in order to account for the elastic support of the rudder body.

Acceptable direct calculation methods are given in Classification Note No. 32.1 "Strength Analysis of Rudder Arrangements". For rudder horns, see also E404.

302 Allowable stresses for the various strength members are given in subsections E to J.

For evaluation of angular deflections, see B204 and G405.

E. Sternframes and Rudder Horns

E 100 General

101 Sternframes and rudder horns shall be effectively attached to the surrounding hull structures. In particular the stern bearing or vertical coupling flange for rudder axle shall be appropriately attached to the transom floor adjacent to the rudder stock.

For semi-spade and spade rudder arrangements structural continuity in the transverse as well as the longitudinal direction shall be specially observed.

102 Cast steel sternframes and welded sternframes shall be strengthened by transverse webs.

Castings shall be of simple design, and sudden changes of section shall be avoided. Where shell plating, floors or other structural parts are welded to the sternframe, there shall be a gradual thickness reduction towards the joint.

Steel forgings and castings for sternframes, rudder horns and rudders shall be in accordance with the requirements in Pt.2 Ch.2 Sec.5 and Sec.7 for general applications.

ANEXO II

Report NAVCAD de RT y BHP

Resistance

4 ago 2017 12:01
HydroComp NavCad 2014

Project ID
Description
File name Hélice.hcnc

Analysis parameters

Vessel drag		ITTC-78 (CT)	Added drag		
Technique:	[Calc]	Prediction	Appendage:	[Calc]	Percentage
Prediction:		Holtrop	Wind:	[Off]	
Reference ship:			Seas:	[Off]	
Model LWL:			Shallow/channel:	[Off]	
Expansion:		Standard	Towed:	[Off]	
Friction line:		ITTC-57	Margin:	[Calc]	Hull drag only [15%]
Hull form factor:	[On]	1,280	**Water properties**		
Speed corr:	[On]		Water type:		Salt
Spray drag corr:	[Off]		Density:		1026,00 kg/m3
Corr allowance:		ITTC-78 (v2008)	Viscosity:		1,18920e-6 m2/s
Roughness [mm]:	[On]	0,15			

Prediction method check [Holtrop]

Parameters	FN [design]	CP	LWL/BWL	BWL/T	Lambda
Value	0,19	0,76	6,39	3,76	0,91
Range	0,06··0,37	0,55··0,85	3,90··14,90	2,10··4,00	0,01··1,07

Prediction results

	SPEED COEFS		ITTC-78 COEFS						
SPEED [kt]	FN	FV	RN	CF	[CTLT/CF]	CR	dCF	CA	CT
3,00 !	0,030	0,072	3,58e8	0,001746	1,280	0,000075	0,000000	0,000412	0,002722
5,00 !	0,049	0,120	5,97e8	0,001634	1,280	0,000100	0,000000	0,000376	0,002567
8,00	0,079	0,192	9,55e8	0,001539	1,280	0,000100	0,000000	0,000329	0,002400
12,00	0,119	0,288	1,43e9	0,001465	1,279	0,000096	0,000000	0,000280	0,002249
15,00	0,148	0,360	1,79e9	0,001426	1,277	0,000125	0,000000	0,000250	0,002195
16,00	0,158	0,384	1,91e9	0,001415	1,276	0,000153	0,000000	0,000241	0,002200
17,50	0,173	0,420	2,09e9	0,001400	1,274	0,000223	0,000000	0,000228	0,002234
18,50	0,183	0,444	2,21e9	0,001391	1,272	0,000289	0,000000	0,000220	0,002278
+ 19,50 +	0,193	0,468	2,33e9	0,001382	1,270	0,000372	0,000000	0,000212	0,002339
20,00	0,198	0,480	2,39e9	0,001378	1,269	0,000421	0,000000	0,000208	0,002377

	RESISTANCE							
SPEED [kt]	RBARE [kN]	RAPP [kN]	RWIND [kN]	RSEAS [kN]	RCHAN [kN]	RTOWED [kN]	RMARGIN [kN]	RTOTAL [kN]
3,00 !	48,95	2,45	0,00	0,00	0,00	7,34	7,34	58,74
5,00 !	128,22	6,41	0,00	0,00	0,00	19,23	19,23	153,86
8,00	306,87	15,34	0,00	0,00	0,00	46,03	46,03	368,24
12,00	647,14	32,36	0,00	0,00	0,00	97,07	97,07	776,57
15,00	987,00	49,35	0,00	0,00	0,00	148,05	148,05	1184,40
16,00	1125,18	56,26	0,00	0,00	0,00	168,78	168,78	1350,22
17,50	1367,09	68,35	0,00	0,00	0,00	205,06	205,06	1640,50
18,50	1557,68	77,88	0,00	0,00	0,00	233,65	233,65	1869,21
+ 19,50 +	1777,20	88,86	0,00	0,00	0,00	266,58	266,58	2132,64
20,00	1899,57	94,98	0,00	0,00	0,00	284,93	284,93	2279,48

	EFFECTIVE POWER		OTHER		
SPEED [kt]	PEBARE [kW]	PETOTAL [kW]	CTLR	CTLT	RBARE/W
3,00 !	75,5	90,7	0,00149	0,05382	0,00005
5,00 !	329,8	395,8	0,00198	0,05075	0,00012
8,00	1262,9	1515,5	0,00198	0,04744	0,00030
12,00	3995,0	4794,0	0,00189	0,04447	0,00063
15,00	7616,4	9139,6	0,00246	0,04340	0,00096
16,00	9261,5	11113,8	0,00303	0,04349	0,00109
17,50	12307,6	14769,1	0,00441	0,04417	0,00132
18,50	14824,8	17789,7	0,00571	0,04503	0,00151
+ 19,50 +	17828,3	21393,9	0,00736	0,04624	0,00172
20,00	19544,4	23453,3	0,00832	0,04699	0,00184

Resistance

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HydroComp NavCad 2014

Project ID
Description
File name Hélice.hcnc

Hull data

General			Planing		
Configuration:		Monohull	Proj chine length:		0,000 m
Chine type:		Round/multiple	Proj bottom area:		0,0 m2
Length on WL:		275,945 m	LCG fwd TR:	[XCG/LP 0,000]	0,000 m
Max beam on WL:	[LWL/BWL 6,388]	43,200 m	VCG below WL:		0,000 m
Max molded draft:	[BWL/T 3,757]	11,500 m	Aft station (fwd TR):		0,000 m
Displacement:	[CB 0,749]	105379,00 t	Deadrise:		0,00 deg
Wetted surface:	[CS 2,764]	14716,7 m2	Chine beam:		0,000 m
ITTC-78 (CT)			Chine ht below WL:		0,000 m
LCB fwd TR:	[XCB/LWL 0,483]	133,199 m	Fwd station (fwd TR):		0,000 m
LCF fwd TR:	[XCF/LWL 0,455]	125,596 m	Deadrise:		0,00 deg
Max section area:	[CX 0,987]	490,4 m2	Chine beam:		0,000 m
Waterplane area:	[CWP 0,834]	9937,3 m2	Chine ht below WL:		0,000 m
Bulb section area:		47,2 m2	Propulsor type:		Propeller
Bulb ctr below WL:		4,010 m	Max prop diameter:		8000,0 mm
Bulb nose fwd TR:		282,962 m	Shaft angle to WL:		0,00 deg
Imm transom area:	[ATR/AX 0,000]	0,0 m2	Position fwd TR:		0,000 m
Transom beam WL:	[BTR/BWL 0,000]	0,000 m	Position below WL:		0,000 m
Transom immersion:	[TTR/T 0,000]	0,000 m	Transom lift device:		Flap
Half entrance angle:		27,00 deg	Device count:		0
Bow shape factor:	[BTK flow]	-1,0	Span:		0,000 m
Stern shape factor:	[WL flow]	1,0	Chord length:		0,000 m
			Deflection angle:		0,00 deg
			Tow point fwd TR:		0,000 m
			Tow point below WL:		0,000 m

Resistance

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HydroComp NavCad 2014

Project ID
Description
File name Hélice.hcnc

Appendage data

General	
Definition:	Percentage
Percent of hull drag:	5,00 %
Planing influence	
LCE fwd TR:	0,000 m
VCE below WL:	0,000 m
Shafting	
Count:	2
Max prop diameter:	8000,0 mm
Shaft angle to WL:	0,00 deg
Exposed shaft length:	0,000 m
Shaft diameter:	0,000 m
Wetted surface:	0,0 m2
Strut bossing length:	0,000 m
Bossing diameter:	0,000 m
Wetted surface:	0,0 m2
Hull bossing length:	0,000 m
Bossing diameter:	0,000 m
Wetted surface:	0,0 m2
Strut (per shaft line)	
Count:	0
Root chord:	0,000 m
Tip chord:	0,000 mm
Span:	0,000 m
T/C ratio:	0,000
Projected area:	0,0 m2
Wetted surface:	0,0 m2
Exposed palm depth:	0,000 m
Exposed palm width:	0,000 m
Rudder	
Count:	0
Rudder location:	Behind propeller
Type:	Balanced foil
Root chord:	0,000 m
Tip chord:	0,000 m
Span:	0,000 m
T/C ratio:	0,000
LE sweep:	0,00 deg
Projected area:	0,0 m2
Wetted surface:	0,0 m2

Skeg/Keel	
Count:	0
Type:	Skeg
Mean length:	0,000 m
Mean width:	0,000 m
Height aft:	0,000 m
Height mid:	0,000 m
Height fwd:	0,000 m
Projected area:	0,0 m2
Wetted surface:	0,0 m2
Stabilizer	
Count:	0
Root chord:	0,000 m
Tip chord:	0,000 m
Span:	0,000 m
T/C ratio:	0,000
LE sweep:	0,00 deg
Wetted surface:	0,0 m2
Projected area:	0,0 m2
Dynamic multiplier:	1,00
Bilge keel	
Count:	0
Mean length:	0,000 m
Mean base width:	0,000 m
Mean projection:	0,000 m
Wetted surface:	0,0 m2
Tunnel thruster	
Count:	0
Diameter:	0,000 m
Sonar dome	
Count:	0
Wetted surface:	0,0 m2
Miscellaneous	
Count:	0
Drag area:	0,0 m2
Drag coef:	0,00

Environment data

Wind	
Wind speed:	0,00 kt
Angle off bow:	0,00 deg
Gradient correction:	Off
Exposed hull	
Transverse area:	0,0 m2
VCE above WL:	0,000 m
Profile area:	0,0 m2
Superstructure	
Superstructure shape:	Cargo ship
Transverse area:	0,0 m2
VCE above WL:	0,000 m
Profile area:	0,0 m2

Seas	
Significant wave ht:	0,000 m
Modal wave period:	0,0 sec
Shallow/channel	
Water depth:	0,000 m
Type:	Shallow water
Channel width:	0,000 m
Channel side slope:	0,00 deg
Hull girth:	0,000 m

Resistance

4 ago 2017 12:01
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Project ID
Description
File name Hélice.hcnc

Symbols and values

SPEED =	Vessel speed
FN =	Froude number [LWL]
FV =	Froude number [VOL]
RN =	Reynolds number [LWL]
CF =	Frictional resistance coefficient
CV/CF =	Viscous/frictional resistance coefficient ratio [dynamic form factor]
CR =	Residuary resistance coefficient
dCF =	Added frictional resistance coefficient for roughness
CA =	Correlation allowance [dynamic]
CT =	Total bare-hull resistance coefficient
RBARE =	Bare-hull resistance
RAPP =	Additional appendage resistance
RWIND =	Additional wind resistance
RSEAS =	Additional sea-state resistance
RCHAN =	Additional shallow/channel resistance
RTOWED =	Additional towed object resistance
RMARGIN =	Resistance margin
RTOTAL =	Total vessel resistance
PEBARE =	Bare-hull effective power
PETOTAL =	Total effective power
CTLR =	Telfer residuary resistance coefficient
CTLT =	Telfer total bare-hull resistance coefficient
RBARE/W =	Bare-hull resistance to weight ratio
+ =	Design speed indicator
* =	Exceeds parameter limit

ANEXO III

Report NAVCAD Cálculo BHP por empuje

Propulsion

9 ago 2017 05:28
HydroComp NavCad 2014

Project ID
Description
File name Hélice.hcnc

Analysis parameters

Hull-propulsor interaction		
Technique:	[Calc]	Prediction
Prediction:		Holtrop
Reference ship:		
Max prop diam:		8000,0 mm
Corrections		
Viscous scale corr:	[On]	Standard
Rudder location:		Behind propeller
Friction line:		ITTC-57
Hull form factor:		1,280
Corr allowance:		ITTC-78 (v2008)
Roughness [mm]:	[Off]	0,15
Ducted prop corr:	[Off]	
Tunnel stern corr:	[Off]	
Effective diam:		
Recess depth:		

System analysis	
Cavitation criteria:	Keller eqn
Analysis type:	Free run
CPP method:	
Engine RPM:	
Mass multiplier:	
RPM constraint:	
Limit [RPM/s]:	
Water properties	
Water type:	Salt
Density:	1026,00 kg/m3
Viscosity:	1,18920e-6 m2/s

Prediction method check [Holtrop]

Parameters	FN [design]	CP	LWL/BWL	BWL/T
Value	0,19	0,76	6,39	3,76
Range	0,06··0,80	0,55··0,85	3,90··14,90	2,10··4,00

Prediction results [System]

	HULL-PROPULSOR				ENGINE			
SPEED [kt]	PETOTAL [kW]	WFT	THD	EFFR	RPMENG [RPM]	PBPROP [kW]	FUEL [L/h]	LOADENG [%]
3,00 !	90,7	0,1658	0,1758	1,0091	116	74,7	---	0,0
5,00 !	395,8	0,1658	0,1758	1,0091	191	324,4	---	0,0
8,00	1515,5	0,1649	0,1758	1,0091	301	1237,6	---	0,0
12,00	4794,0	0,1642	0,1758	1,0091	446	3904,7	---	0,0
15,00	9139,6	0,1638	0,1758	1,0091	555	7439,7	---	0,0
16,00	11113,8	0,1637	0,1758	1,0091	592	9048,5	---	0,0
17,50	14769,1	0,1636	0,1758	1,0091	650	12033,9	---	0,0
18,50	17789,7	0,1635	0,1758	1,0091	690	14509,2	---	0,0
+ 19,50 +	21393,9	0,1634	0,1758	1,0091	731	17473,4	---	0,0
20,00	23453,3	0,1633	0,1758	1,0091	753	19172,9	---	0,0

	POWER DELIVERY							
SPEED [kt]	RPMPROP [RPM]	QPROP [kN·m]	QENG [kN·m]	PDPROP [kW]	PSPROP [kW]	PSTOTAL [kW]	PBTOTAL [kW]	TRANSP
3,00 !	15	43,73	5,83	70,2	72,4	144,8	149,3	---
5,00 !	25	115,49	15,40	305,2	314,6	629,3	648,7	---
8,00	40	279,28	37,24	1164,5	1200,5	2401,0	2475,2	---
12,00	59	595,16	79,35	3673,9	3787,6	7575,1	7809,4	816,9
15,00	74	911,45	121,53	7000,0	7216,5	14433,0	14879,4	535,9
16,00	79	1038,77	138,50	8513,7	8777,1	17554,1	18097,0	470,0
17,50	87	1258,95	167,86	11322,7	11672,8	23345,7	24067,7	386,6
18,50	92	1430,04	190,67	13651,7	14073,9	28147,8	29018,3	338,9
+ 19,50 +	98	1624,77	216,64	16440,7	16949,2	33898,3	34946,7	296,6
20,00	100	1732,35	230,98	18039,8	18597,7	37195,4	38345,8	277,3

	EFFICIENCY				THRUST	
SPEED [kt]	EFFO	EFFG	EFFOA	MERIT	THRPROP [kN]	DELTHR [kN]
3,00 !	0,6473	0,9700	0,6259	0,41789	35,64	58,74
5,00 !	0,6504	0,9700	0,6289	0,40775	93,34	153,86
8,00	0,6534	0,9700	0,6312	0,39568	223,40	368,24
12,00	0,6557	0,9700	0,6329	0,38407	471,12	776,56
15,00	0,6564	0,9700	0,6332	0,37968	718,54	1184,39
16,00	0,6563	0,9700	0,6331	0,37998	819,15	1350,22
17,50	0,6559	0,9700	0,6326	0,38264	995,24	1640,48
18,50	0,6554	0,9700	0,6320	0,38599	1134,00	1869,21
+ 19,50 +	0,6545	0,9700	0,6311	0,3906	1293,81	2132,62
20,00	0,6539	0,9700	0,6305	0,39336	1382,89	2279,46

Propulsion

9 ago 2017 05:28
HydroComp NavCad 2014

Project ID
Description
File name Hélice.hcnc

Prediction results [Propulsor]

	PROPULSOR COEFS								
SPEED [kt]	J	KT	KQ	KTJ2	KQJ3	CTH	CP	RNPROP	
3,00 !	0,6238	0,1274	0,01954	0,32739	0,080503	0,83369	1,2764	1,61e7	
5,00 !	0,6320	0,1233	0,01907	0,30872	0,075548	0,78614	1,1978	2,66e7	
8,00	0,6416	0,1185	0,01852	0,28801	0,070152	0,73342	1,1123	4,20e7	
12,00	0,6506	0,1141	0,01801	0,26948	0,065412	0,68623	1,0371	6,22e7	
15,00	0,6539	0,1124	0,01782	0,26281	0,063726	0,66924	1,0104	7,74e7	
16,00	0,6537	0,1125	0,01783	0,26326	0,06384	0,67039	1,0122	8,26e7	
17,50	0,6517	0,1135	0,01795	0,26728	0,064855	0,68063	1,0283	9,06e7	
18,50	0,6491	0,1148	0,01809	0,27246	0,066167	0,6938	1,0491	9,62e7	
+ 19,50 +	0,6455	0,1166	0,01830	0,27973	0,068024	0,71233	1,0785	1,02e8	
20,00	0,6434	0,1176	0,01842	0,2842	0,069171	0,72372	1,0967	1,05e8	
	CAVITATION								
SPEED [kt]	SIGMAV	SIGMAN	SIGMA07R	TIPSPEED [m/s]	MINBAR	PRESS [kPa]	CAVAVG [%]	CAVMAX [%]	PITCHFC [mm]
3,00 !	117,24	45,62	8,73	6,48	0,072	0,80	2,0	2,0	5874,1
5,00 !	42,21	16,86	3,22	10,67	0,094	2,10	2,0	2,0	5906,6
8,00	16,45	6,77	1,29	16,83	0,145	5,03	2,0	2,0	5944,9
12,00	7,30	3,09	0,59	24,92	0,241	10,61	2,0	2,0	5981,3
15,00	4,67	2,00	0,38	31,00	0,338	16,19	2,0	2,0	5995,0
16,00	4,10	1,75	0,33	33,08	0,377	18,45	2,0	2,0	5994,0
17,50	3,43	1,46	0,28	36,30	0,446	22,42	2,0	2,0	5985,8
18,50	3,07	1,29	0,25	38,53	0,501	25,55	2,0	2,0	5975,3
+ 19,50 +	2,76	1,15	0,22	40,84	0,564	29,15	2,0	2,0	5960,9
20,00	2,62	1,09	0,21	42,03	0,599	31,16	2,2	2,2	5952,2

Propulsion

9 ago 2017 05:28
HydroComp NavCad 2014

Project ID
Description
File name Hélice.hcnc

Hull data

General			Planing		
Configuration:		Monohull	Proj chine length:		0,000 m
Chine type:		Round/multiple	Proj bottom area:		0,0 m2
Length on WL:		275,945 m	LCG fwd TR:	[XCG/LP 0,000]	0,000 m
Max beam on WL:	[LWL/BWL 6,388]	43,200 m	VCG below WL:		0,000 m
Max molded draft:	[BWL/T 3,757]	11,500 m	Aft station (fwd TR):		0,000 m
Displacement:	[CB 0,749]	105379,00 t	Deadrise:		0,00 deg
Wetted surface:	[CS 2,764]	14716,7 m2	Chine beam:		0,000 m
ITTC-78 (CT)			Chine ht below WL:		0,000 m
LCB fwd TR:	[XCB/LWL 0,483]	133,199 m	Fwd station (fwd TR):		0,000 m
LCF fwd TR:	[XCF/LWL 0,455]	125,596 m	Deadrise:		0,00 deg
Max section area:	[CX 0,987]	490,4 m2	Chine beam:		0,000 m
Waterplane area:	[CWP 0,834]	9937,3 m2	Chine ht below WL:		0,000 m
Bulb section area:		47,2 m2	Propulsor type:		Propeller
Bulb ctr below WL:		4,010 m	Max prop diameter:		8000,0 mm
Bulb nose fwd TR:		282,962 m	Shaft angle to WL:		0,00 deg
Imm transom area:	[ATR/AX 0,000]	0,0 m2	Position fwd TR:		0,000 m
Transom beam WL:	[BTR/BWL 0,000]	0,000 m	Position below WL:		0,000 m
Transom immersion:	[TTR/T 0,000]	0,000 m	Transom lift device:		Flap
Half entrance angle:		27,00 deg	Device count:		0
Bow shape factor:	[BTK flow]	-1,0	Span:		0,000 m
Stern shape factor:	[WL flow]	1,0	Chord length:		0,000 m
			Deflection angle:		0,00 deg
			Tow point fwd TR:		0,000 m
			Tow point below WL:		0,000 m

Propulsor data

Propulsor				Propeller options	
Count:		2		Oblique angle corr:	Off
Propulsor type:		Propeller series		Shaft angle to WL:	0,00 deg
Propeller type:		FPP		Added rise of run:	0,00 deg
Propeller series:		B Series		Propeller cup:	0,0 mm
Propeller sizing:		By thrust		KTKQ corrections:	Standard
Reference prop:				Scale correction:	Full ITTC
Blade count:		4		KT multiplier:	1,000
Expanded area ratio:		0,8831	[Size]	KQ multiplier:	1,000
Propeller diameter:		8000,0 mm	[Size]	Blade T/C [0.7R]:	Standard
Propeller mean pitch:	[P/D 0,8400]	6720,0 mm	[Keep]	Roughness:	Standard
Hub immersion:		6,9 mm		Cav breakdown:	Off
Engine/gear				**Design condition**	
Engine data:				Max prop diam:	8000,0 mm
Rated RPM:		0 RPM		Design speed:	19,50 kt
Rated power:		0,0 kW		Reference power:	44000,0 kW
Gear efficiency:		0,970		Design point:	0,850
Load correction:		Off		Reference RPM:	600,0
Gear ratio:		7,500	[Keep]	Design point:	1,000
Shaft efficiency:		0,970			

Symbols and values

SPEED = Vessel speed

PETOTAL = Total vessel effective power
WFT = Taylor wake fraction coefficient
THD = Thrust deduction coefficient
EFFR = Relative-rotative efficiency

RPMENG = Engine RPM
PBPROP = Brake power per propulsor
FUEL = Fuel rate per engine
LOADENG = Percentage of engine max available power at given RPM

RPMPROP = Propulsor RPM
QPROP = Propulsor open water torque
QENG = Engine torque
PDPROP = Delivered power per propulsor
PSPROP = Shaft power per propulsor
PSTOTAL = Total vessel shaft power
PBTOTAL = Total vessel brake power
TRANSP = Transport factor

EFFO = Propulsor open-water efficiency
EFFG = Gear efficiency (load corrected)
EFFOA = Overall propulsion efficiency [=PETOTAL/PSTOTAL]
MERIT = Propulsor merit coefficient

THRPROP = Open-water thrust per propulsor
DELTHR = Total vessel delivered thrust

J = Propulsor advance coefficient
KT = Propulsor thrust coefficient [horizontal, if in oblique flow]
KQ = Propulsor torque coefficient
KTJ2 = Propulsor thrust loading ratio
KQJ3 = Propulsor torque loading ratio
CTH = Horizontal component of bare-hull resistance coefficient
CP = Propulsor thrust loading coefficient
RNPROP = Propeller Reynolds number at 0.7R

SIGMAV = Cavitation number of propeller by vessel speed
SIGMAN = Cavitation number of propeller by RPM
SIGMA07R = Cavitation number of blade section at 0.7R
TIPSPEED = Propeller circumferential tip speed
MINBAR = Minimum expanded blade area ratio recommended by selected cavitation criteria
PRESS = Average propeller loading pressure
CAVAVG = Average predicted back cavitation percentage
CAVMAX = Peak predicted back cavitation percentage [if in oblique flow]
PITCHFC = Minimum recommended pitch to avoid face cavitation

+ = Design speed indicator
* = Exceeds recommended parameter limit
! = Exceeds recommended cavitation criteria [warning]
!! = Substantially exceeds recommended cavitation criteria [critical]
!!! = Thrust breakdown is indicated [severe]
--- = Insignificant or not applicable

ANEXO IV

Report NAVCAD Cálculo BHP. Hélice de 4 palas

Propulsion

9 ago 2017 06:59
HydroComp NavCad 2014

Project ID
Description
File name Hélice.hcnc

Analysis parameters

Hull-propulsor interaction		
Technique:	[Calc]	Prediction
Prediction:		Holtrop
Reference ship:		
Max prop diam:		8000,0 mm
Corrections		
Viscous scale corr:	[On]	Standard
Rudder location:		Behind propeller
Friction line:		ITTC-57
Hull form factor:		1,280
Corr allowance:		ITTC-78 (v2008)
Roughness [mm]:	[Off]	0,15
Ducted prop corr:	[Off]	
Tunnel stern corr:	[Off]	
Effective diam:		
Recess depth:		

System analysis	
Cavitation criteria:	Keller eqn
Analysis type:	Free run
CPP method:	
Engine RPM:	
Mass multiplier:	
RPM constraint:	
Limit [RPM/s]:	
Water properties	
Water type:	Salt
Density:	1026,00 kg/m3
Viscosity:	1,18920e-6 m2/s

Prediction method check [Holtrop]

Parameters	FN [design]	CP	LWL/BWL	BWL/T
Value	0,19	0,76	6,39	3,76
Range	0,06··0,80	0,55··0,85	3,90··14,90	2,10··4,00

Prediction results [System]

	HULL-PROPULSOR				ENGINE			
SPEED [kt]	PETOTAL [kW]	WFT	THD	EFFR	RPMENG [RPM]	PBPROP [kW]	FUEL [L/h]	LOADENG [%]
3,00 !	90,7	0,1658	0,1758	1,0097	117	75,2	---	0,0
5,00 !	395,8	0,1658	0,1758	1,0097	193	326,9	---	0,0
8,00	1515,5	0,1649	0,1758	1,0097	304	1247,9	---	0,0
12,00	4794,0	0,1642	0,1758	1,0097	451	3939,3	---	0,0
15,00	9139,6	0,1638	0,1758	1,0097	561	7507,4	---	0,0
16,00	11113,8	0,1637	0,1758	1,0097	598	9130,6	---	0,0
17,50	14769,1	0,1636	0,1758	1,0097	656	12141,4	---	0,0
18,50	17789,7	0,1635	0,1758	1,0097	697	14636,4	---	0,0
+ 19,50 +	21393,9	0,1634	0,1758	1,0097	739	17622,5	---	0,0
20,00	23453,3	0,1633	0,1758	1,0097	760	19334,0	---	0,0

	POWER DELIVERY							
SPEED [kt]	RPMPROP [RPM]	QPROP [kN·m]	QENG [kN·m]	PDPROP [kW]	PSPROP [kW]	PSTOTAL [kW]	PBTOTAL [kW]	TRANSP
3,00 !	16	43,65	5,82	70,8	72,9	145,9	150,4	---
5,00 !	26	115,33	15,38	307,6	317,1	634,1	653,7	---
8,00	41	279,01	37,20	1174,1	1210,4	2420,9	2495,7	---
12,00	60	594,87	79,32	3706,5	3821,1	7642,2	7878,6	809,7
15,00	75	911,17	121,49	7063,7	7282,1	14564,3	15014,7	531,1
16,00	80	1038,43	138,46	8591,0	8856,7	17713,3	18261,2	465,8
17,50	88	1258,40	167,79	11423,8	11777,1	23554,3	24282,8	383,1
18,50	93	1429,22	190,56	13771,3	14197,3	28394,5	29272,7	336,0
+ 19,50 +	98	1623,52	216,47	16581,0	17093,8	34187,7	35245,0	294,1
20,00	101	1730,83	230,78	18191,3	18754,0	37507,9	38668,0	275,0

	EFFICIENCY				THRUST	
SPEED [kt]	EFFO	EFFG	EFFOA	MERIT	THRPROP [kN]	DELTHR [kN]
3,00 !	0,6422	0,9700	0,6214	0,41465	35,64	58,74
5,00 !	0,6450	0,9700	0,6241	0,4044	93,34	153,86
8,00	0,6477	0,9700	0,6260	0,39222	223,40	368,24
12,00	0,6496	0,9700	0,6273	0,38049	471,12	776,56
15,00	0,6501	0,9700	0,6275	0,37606	718,55	1184,40
16,00	0,6501	0,9700	0,6274	0,37636	819,15	1350,22
17,50	0,6497	0,9700	0,6270	0,37904	995,24	1640,49
18,50	0,6493	0,9700	0,6265	0,38243	1134,00	1869,21
+ 19,50 +	0,6486	0,9700	0,6258	0,38708	1293,81	2132,62
20,00	0,6481	0,9700	0,6253	0,38987	1382,89	2279,46

Propulsion

9 ago 2017 06:59
HydroComp NavCad 2014

Project ID
Description
File name Hélice.hcnc

Prediction results [Propulsor]

	PROPULSOR COEFS								
SPEED [kt]	J	KT	KQ	KTJ2	KQJ3	CTH	CP	RNPROP	
3,00 !	0,6178	0,1250	0,01913	0,32739	0,081132	0,83369	1,2857	1,66e7	
5,00 !	0,6259	0,1209	0,01868	0,30872	0,076173	0,78614	1,2071	2,74e7	
8,00	0,6353	0,1163	0,01815	0,28801	0,070773	0,73342	1,1215	4,32e7	
12,00	0,6442	0,1118	0,01765	0,26948	0,066028	0,68623	1,0463	6,41e7	
15,00	0,6475	0,1102	0,01746	0,26281	0,064341	0,66925	1,0196	7,97e7	
16,00	0,6472	0,1103	0,01748	0,26326	0,064454	0,67039	1,0214	8,51e7	
17,50	0,6452	0,1113	0,01759	0,26728	0,06547	0,68063	1,0375	9,33e7	
18,50	0,6427	0,1125	0,01773	0,27246	0,066784	0,6938	1,0583	9,90e7	
+ 19,50 +	0,6392	0,1143	0,01793	0,27973	0,068642	0,71233	1,0877	1,05e8	
20,00	0,6371	0,1154	0,01805	0,2842	0,06979	0,72372	1,1059	1,08e8	
	CAVITATION								
SPEED [kt]	SIGMAV	SIGMAN	SIGMA07R	TIPSPEED [m/s]	MINBAR	PRESS [kPa]	CAVAVG [%]	CAVMAX [%]	PITCHFC [mm]
3,00 !	117,24	44,75	8,58	6,55	0,073	0,79	2,0	2,0	5817,9
5,00 !	42,21	16,54	3,16	10,77	0,095	2,06	2,0	2,0	5849,7
8,00	16,45	6,64	1,27	17,00	0,145	4,93	2,0	2,0	5887,1
12,00	7,30	3,03	0,58	25,16	0,242	10,40	2,0	2,0	5922,6
15,00	4,67	1,96	0,37	31,31	0,338	15,86	2,0	2,0	5935,9
16,00	4,10	1,72	0,33	33,41	0,378	18,08	2,0	2,0	5935,0
17,50	3,43	1,43	0,27	36,66	0,447	21,97	2,0	2,0	5927,0
18,50	3,07	1,27	0,24	38,92	0,501	25,04	2,0	2,0	5916,8
+ 19,50 +	2,76	1,13	0,21	41,25	0,564	28,56	2,0	2,0	5902,7
20,00	2,62	1,06	0,20	42,45	0,599	30,53	2,0	2,0	5894,2

Propulsion

9 ago 2017 06:59
HydroComp NavCad 2014

Project ID
Description
File name Hélice.hcnc

Hull data

General			Planing		
Configuration:		Monohull	Proj chine length:		0,000 m
Chine type:		Round/multiple	Proj bottom area:		0,0 m2
Length on WL:		275,945 m	LCG fwd TR:	[XCG/LP 0,000]	0,000 m
Max beam on WL:	[LWL/BWL 6,388]	43,200 m	VCG below WL:		0,000 m
Max molded draft:	[BWL/T 3,757]	11,500 m	Aft station (fwd TR):		0,000 m
Displacement:	[CB 0,749]	105379,00 t	Deadrise:		0,00 deg
Wetted surface:	[CS 2,764]	14716,7 m2	Chine beam:		0,000 m
ITTC-78 (CT)			Chine ht below WL:		0,000 m
LCB fwd TR:	[XCB/LWL 0,483]	133,199 m	Fwd station (fwd TR):		0,000 m
LCF fwd TR:	[XCF/LWL 0,455]	125,596 m	Deadrise:		0,00 deg
Max section area:	[CX 0,987]	490,4 m2	Chine beam:		0,000 m
Waterplane area:	[CWP 0,834]	9937,3 m2	Chine ht below WL:		0,000 m
Bulb section area:		47,2 m2	Propulsor type:		Propeller
Bulb ctr below WL:		4,010 m	Max prop diameter:		8000,0 mm
Bulb nose fwd TR:		282,962 m	Shaft angle to WL:		0,00 deg
Imm transom area:	[ATR/AX 0,000]	0,0 m2	Position fwd TR:		0,000 m
Transom beam WL:	[BTR/BWL 0,000]	0,000 m	Position below WL:		0,000 m
Transom immersion:	[TTR/T 0,000]	0,000 m	Transom lift device:		Flap
Half entrance angle:		27,00 deg	Device count:		0
Bow shape factor:	[BTK flow]	-1,0	Span:		0,000 m
Stern shape factor:	[WL flow]	1,0	Chord length:		0,000 m
			Deflection angle:		0,00 deg
			Tow point fwd TR:		0,000 m
			Tow point below WL:		0,000 m

Propulsor data

Propulsor				Propeller options	
Count:		2		Oblique angle corr:	Off
Propulsor type:		Propeller series		Shaft angle to WL:	0,00 deg
Propeller type:		FPP		Added rise of run:	0,00 deg
Propeller series:		B Series		Propeller cup:	0,0 mm
Propeller sizing:		By power		KTKQ corrections:	Standard
Reference prop:				Scale correction:	Full ITTC
Blade count:		4		KT multiplier:	1,000
Expanded area ratio:		0,9011	[Size]	KQ multiplier:	1,000
Propeller diameter:		8000,0 mm	[Size]	Blade T/C [0.7R]:	Standard
Propeller mean pitch:	[P/D 0,8313]	6650,0 mm	[Keep]	Roughness:	Standard
Hub immersion:		6,9 mm		Cav breakdown:	Off
Engine/gear				**Design condition**	
Engine data:				Max prop diam:	8000,0 mm
Rated RPM:		0 RPM		Design speed:	19,50 kt
Rated power:		0,0 kW		Reference power:	44000,0 kW
Gear efficiency:		0,970		Design point:	0,850
Load correction:		Off		Reference RPM:	600,0
Gear ratio:		7,500	[Keep]	Design point:	1,000
Shaft efficiency:		0,970			

Project ID
Description
File name Hélice.hcnc

Symbols and values

SPEED =	Vessel speed
PETOTAL =	Total vessel effective power
WFT =	Taylor wake fraction coefficient
THD =	Thrust deduction coefficient
EFFR =	Relative-rotative efficiency
RPMENG =	Engine RPM
PBPROP =	Brake power per propulsor
FUEL =	Fuel rate per engine
LOADENG =	Percentage of engine max available power at given RPM
RPMPROP =	Propulsor RPM
QPROP =	Propulsor open water torque
QENG =	Engine torque
PDPROP =	Delivered power per propulsor
PSPROP =	Shaft power per propulsor
PSTOTAL =	Total vessel shaft power
PBTOTAL =	Total vessel brake power
TRANSP =	Transport factor
EFFO =	Propulsor open-water efficiency
EFFG =	Gear efficiency (load corrected)
EFFOA =	Overall propulsion efficiency [=PETOTAL/PSTOTAL]
MERIT =	Propulsor merit coefficient
THRPROP =	Open-water thrust per propulsor
DELTHR =	Total vessel delivered thrust
J =	Propulsor advance coefficient
KT =	Propulsor thrust coefficient [horizontal, if in oblique flow]
KQ =	Propulsor torque coefficient
KTJ2 =	Propulsor thrust loading ratio
KQJ3 =	Propulsor torque loading ratio
CTH =	Horizontal component of bare-hull resistance coefficient
CP =	Propulsor thrust loading coefficient
RNPROP =	Propeller Reynolds number at 0.7R
SIGMAV =	Cavitation number of propeller by vessel speed
SIGMAN =	Cavitation number of propeller by RPM
SIGMA07R =	Cavitation number of blade section at 0.7R
TIPSPEED =	Propeller circumferential tip speed
MINBAR =	Minimum expanded blade area ratio recommended by selected cavitation criteria
PRESS =	Average propeller loading pressure
CAVAVG =	Average predicted back cavitation percentage
CAVMAX =	Peak predicted back cavitation percentage [if in oblique flow]
PITCHFC =	Minimum recommended pitch to avoid face cavitation
+ =	Design speed indicator
* =	Exceeds recommended parameter limit
! =	Exceeds recommended cavitation criteria [warning]
!! =	Substantially exceeds recommended cavitation criteria [critical]
!!! =	Thrust breakdown is indicated [severe]
--- =	Insignificant or not applicable

ANEXO V

Report NAVCAD Hélice de 5 palas

Propulsion

9 ago 2017 07:09
HydroComp NavCad 2014

Project ID
Description
File name Hélice.hcnc

Analysis parameters

Hull-propulsor interaction		
Technique:	[Calc]	Prediction
Prediction:		Holtrop
Reference ship:		
Max prop diam:		8000,0 mm
Corrections		
Viscous scale corr:	[On]	Standard
Rudder location:		Behind propeller
Friction line:		ITTC-57
Hull form factor:		1,280
Corr allowance:		ITTC-78 (v2008)
Roughness [mm]:	[Off]	0,15
Ducted prop corr:	[Off]	
Tunnel stern corr:	[Off]	
Effective diam:		
Recess depth:		

System analysis	
Cavitation criteria:	Keller eqn
Analysis type:	Free run
CPP method:	
Engine RPM:	
Mass multiplier:	
RPM constraint:	
Limit [RPM/s]:	
Water properties	
Water type:	Salt
Density:	1026,00 kg/m3
Viscosity:	1,18920e-6 m2/s

Prediction method check [Holtrop]

Parameters	FN [design]	CP	LWL/BWL	BWL/T
Value	0,19	0,76	6,39	3,76
Range	0,06··0,80	0,55··0,85	3,90··14,90	2,10··4,00

Prediction results [System]

	HULL-PROPULSOR				ENGINE			
SPEED [kt]	PETOTAL [kW]	WFT	THD	EFFR	RPMENG [RPM]	PBPROP [kW]	FUEL [L/h]	LOADENG [%]
3,00 !	90,7	0,1658	0,1758	1,0097	116	75,8	---	0,0
5,00 !	395,8	0,1658	0,1758	1,0097	190	329,8	---	0,0
8,00	1515,5	0,1649	0,1758	1,0097	300	1261,3	---	0,0
12,00	4794,0	0,1642	0,1758	1,0097	445	3988,9	---	0,0
15,00	9139,6	0,1638	0,1758	1,0097	553	7607,1	---	0,0
16,00	11113,8	0,1637	0,1758	1,0097	590	9251,4	---	0,0
17,50	14769,1	0,1636	0,1758	1,0097	648	12297,1	---	0,0
18,50	17789,7	0,1635	0,1758	1,0097	687	14816,2	---	0,0
+ 19,50 +	21393,9	0,1634	0,1758	1,0097	729	17826,8	---	0,0
20,00	23453,3	0,1633	0,1758	1,0097	750	19549,8	---	0,0

	POWER DELIVERY							
SPEED [kt]	RPMPROP [RPM]	QPROP [kN·m]	QENG [kN·m]	PDPROP [kW]	PSPROP [kW]	PSTOTAL [kW]	PBTOTAL [kW]	TRANSP
3,00 !	15	44,60	5,95	71,3	73,5	147,0	151,5	---
5,00 !	25	118,00	15,73	310,3	319,9	639,9	659,6	---
8,00	40	285,90	38,12	1186,8	1223,5	2447,0	2522,7	---
12,00	59	610,50	81,40	3753,2	3869,2	7738,5	7977,8	799,7
15,00	74	935,67	124,76	7157,5	7378,9	14757,7	15214,2	524,2
16,00	79	1066,31	142,18	8704,7	8973,9	17947,8	18502,9	459,7
17,50	86	1291,73	172,23	11570,4	11928,2	23856,4	24594,3	378,3
18,50	92	1466,39	195,52	13940,6	14371,7	28743,5	29632,4	331,9
+ 19,50 +	97	1664,74	221,97	16773,2	17292,0	34584,0	35653,6	290,8
20,00	100	1774,12	236,55	18394,4	18963,3	37926,6	39099,6	271,9

	EFFICIENCY				THRUST	
SPEED [kt]	EFFO	EFFG	EFFOA	MERIT	THRPROP [kN]	DELTHR [kN]
3,00 !	0,6374	0,9700	0,6167	0,41153	35,64	58,74
5,00 !	0,6393	0,9700	0,6185	0,40078	93,34	153,86
8,00	0,6408	0,9700	0,6193	0,38802	223,40	368,24
12,00	0,6415	0,9700	0,6195	0,37576	471,12	776,56
15,00	0,6416	0,9700	0,6193	0,37113	718,55	1184,40
16,00	0,6416	0,9700	0,6192	0,37144	819,15	1350,22
17,50	0,6415	0,9700	0,6191	0,37425	995,25	1640,50
18,50	0,6414	0,9700	0,6189	0,37778	1134,00	1869,20
+ 19,50 +	0,6412	0,9700	0,6186	0,38265	1293,82	2132,64
20,00	0,6410	0,9700	0,6184	0,38557	1382,90	2279,47

Propulsion

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Prediction results [Propulsor]

	PROPULSOR COEFS								
SPEED [kt]	J	KT	KQ	KTJ2	KQJ3	CTH	CP	RNPROP	
3,00 !	0,6266	0,1285	0,02011	0,32739	0,081747	0,83369	1,2954	1,43e7	
5,00 !	0,6347	0,1244	0,01965	0,30872	0,076861	0,78614	1,218	2,35e7	
8,00	0,6440	0,1195	0,01911	0,28801	0,071538	0,73342	1,1336	3,71e7	
12,00	0,6529	0,1149	0,01861	0,26948	0,06686	0,68623	1,0595	5,50e7	
15,00	0,6562	0,1132	0,01842	0,26281	0,065196	0,66925	1,0331	6,85e7	
16,00	0,6559	0,1133	0,01843	0,26326	0,065307	0,67039	1,0349	7,31e7	
17,50	0,6539	0,1143	0,01854	0,26728	0,06631	0,68063	1,0508	8,02e7	
18,50	0,6514	0,1156	0,01869	0,27246	0,067604	0,6938	1,0713	8,51e7	
+ 19,50 +	0,6479	0,1174	0,01889	0,27973	0,069438	0,71234	1,1003	9,02e7	
20,00	0,6458	0,1185	0,01901	0,2842	0,070569	0,72372	1,1183	9,27e7	

	CAVITATION								
SPEED [kt]	SIGMAV	SIGMAN	SIGMA07R	TIPSPEED [m/s]	MINBAR	PRESS [kPa]	CAVAVG [%]	CAVMAX [%]	PITCHFC [mm]
3,00 !	117,24	46,03	8,80	6,46	0,074	0,72	2,0	2,0	5900,3
5,00 !	42,21	17,00	3,25	10,62	0,099	1,89	2,0	2,0	5931,5
8,00	16,45	6,82	1,30	16,77	0,155	4,53	2,0	2,0	5968,0
12,00	7,30	3,11	0,59	24,83	0,263	9,56	2,0	2,0	6002,6
15,00	4,67	2,01	0,38	30,89	0,372	14,59	2,0	2,0	6015,6
16,00	4,10	1,76	0,34	32,97	0,416	16,63	2,0	2,0	6014,7
17,50	3,43	1,47	0,28	36,18	0,493	20,20	2,0	2,0	6006,9
18,50	3,07	1,30	0,25	38,40	0,554	23,02	2,0	2,0	5997,0
+ 19,50 +	2,76	1,16	0,22	40,69	0,625	26,26	2,0	2,0	5983,2
20,00	2,62	1,09	0,21	41,87	0,664	28,07	2,0	2,0	5975,0

Propulsion

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Hull data

General			Planing		
Configuration:		Monohull	Proj chine length:		0,000 m
Chine type:		Round/multiple	Proj bottom area:		0,0 m2
Length on WL:		275,945 m	LCG fwd TR:	[XCG/LP 0,000]	0,000 m
Max beam on WL:	[LWL/BWL 6,388]	43,200 m	VCG below WL:		0,000 m
Max molded draft:	[BWL/T 3,757]	11,500 m	Aft station (fwd TR):		0,000 m
Displacement:	[CB 0,749]	105379,00 t	Deadrise:		0,00 deg
Wetted surface:	[CS 2,764]	14716,7 m2	Chine beam:		0,000 m
ITTC-78 (CT)			Chine ht below WL:		0,000 m
LCB fwd TR:	[XCB/LWL 0,483]	133,199 m	Fwd station (fwd TR):		0,000 m
LCF fwd TR:	[XCF/LWL 0,455]	125,596 m	Deadrise:		0,00 deg
Max section area:	[CX 0,987]	490,4 m2	Chine beam:		0,000 m
Waterplane area:	[CWP 0,834]	9937,3 m2	Chine ht below WL:		0,000 m
Bulb section area:		47,2 m2	Propulsor type:		Propeller
Bulb ctr below WL:		4,010 m	Max prop diameter:		8000,0 mm
Bulb nose fwd TR:		282,962 m	Shaft angle to WL:		0,00 deg
Imm transom area:	[ATR/AX 0,000]	0,0 m2	Position fwd TR:		0,000 m
Transom beam WL:	[BTR/BWL 0,000]	0,000 m	Position below WL:		0,000 m
Transom immersion:	[TTR/T 0,000]	0,000 m	Transom lift device:		Flap
Half entrance angle:		27,00 deg	Device count:		0
Bow shape factor:	[BTK flow]	-1,0	Span:		0,000 m
Stern shape factor:	[WL flow]	1,0	Chord length:		0,000 m
			Deflection angle:		0,00 deg
			Tow point fwd TR:		0,000 m
			Tow point below WL:		0,000 m

Propulsor data

Propulsor				Propeller options	
Count:		2		Oblique angle corr:	Off
Propulsor type:		Propeller series		Shaft angle to WL:	0,00 deg
Propeller type:		FPP		Added rise of run:	0,00 deg
Propeller series:		B Series		Propeller cup:	0,0 mm
Propeller sizing:		By power		KTKQ corrections:	Standard
Reference prop:				Scale correction:	Full ITTC
Blade count:		5		KT multiplier:	1,000
Expanded area ratio:		0,9801	[Size]	KQ multiplier:	1,000
Propeller diameter:		8000,0 mm	[Size]	Blade T/C [0.7R]:	Standard
Propeller mean pitch:	[P/D 0,8313]	6650,0 mm	[Keep]	Roughness:	Standard
Hub immersion:		6,9 mm		Cav breakdown:	Off
Engine/gear				**Design condition**	
Engine data:				Max prop diam:	8000,0 mm
Rated RPM:		0 RPM		Design speed:	19,50 kt
Rated power:		0,0 kW		Reference power:	44000,0 kW
Gear efficiency:		0,970		Design point:	0,850
Load correction:		Off		Reference RPM:	600,0
Gear ratio:		7,500	[Keep]	Design point:	1,000
Shaft efficiency:		0,970			

Propulsion

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Symbols and values

SPEED = Vessel speed

PETOTAL = Total vessel effective power
WFT = Taylor wake fraction coefficient
THD = Thrust deduction coefficient
EFFR = Relative-rotative efficiency

RPMENG = Engine RPM
PBPROP = Brake power per propulsor
FUEL = Fuel rate per engine
LOADENG = Percentage of engine max available power at given RPM

RPMPROP = Propulsor RPM
QPROP = Propulsor open water torque
QENG = Engine torque
PDPROP = Delivered power per propulsor
PSPROP = Shaft power per propulsor
PSTOTAL = Total vessel shaft power
PBTOTAL = Total vessel brake power
TRANSP = Transport factor

EFFO = Propulsor open-water efficiency
EFFG = Gear efficiency (load corrected)
EFFOA = Overall propulsion efficiency [=PETOTAL/PSTOTAL]
MERIT = Propulsor merit coefficient

THRPROP = Open-water thrust per propulsor
DELTHR = Total vessel delivered thrust

J = Propulsor advance coefficient
KT = Propulsor thrust coefficient [horizontal, if in oblique flow]
KQ = Propulsor torque coefficient
KTJ2 = Propulsor thrust loading ratio
KQJ3 = Propulsor torque loading ratio
CTH = Horizontal component of bare-hull resistance coefficient
CP = Propulsor thrust loading coefficient
RNPROP = Propeller Reynolds number at 0.7R

SIGMAV = Cavitation number of propeller by vessel speed
SIGMAN = Cavitation number of propeller by RPM
SIGMA07R = Cavitation number of blade section at 0.7R
TIPSPEED = Propeller circumferential tip speed
MINBAR = Minimum expanded blade area ratio recommended by selected cavitation criteria
PRESS = Average propeller loading pressure
CAVAVG = Average predicted back cavitation percentage
CAVMAX = Peak predicted back cavitation percentage [if in oblique flow]
PITCHFC = Minimum recommended pitch to avoid face cavitation

+ = Design speed indicator
* = Exceeds recommended parameter limit
! = Exceeds recommended cavitation criteria [warning]
!! = Substantially exceeds recommended cavitation criteria [critical]
!!! = Thrust breakdown is indicated [severe]
--- = Insignificant or not applicable

ANEXO VI

Report NAVCAD Hélice de 6 palas

Propulsion

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Project ID
Description
File name Hélice.hcnc

Analysis parameters

Hull-propulsor interaction		
Technique:	[Calc]	Prediction
Prediction:		Holtrop
Reference ship:		
Max prop diam:		8000,0 mm
Corrections		
Viscous scale corr:	[On]	Standard
Rudder location:		Behind propeller
Friction line:		ITTC-57
Hull form factor:		1,280
Corr allowance:		ITTC-78 (v2008)
Roughness [mm]:	[Off]	0,15
Ducted prop corr:	[Off]	
Tunnel stern corr:	[Off]	
Effective diam:		
Recess depth:		

System analysis	
Cavitation criteria:	Keller eqn
Analysis type:	Free run
CPP method:	
Engine RPM:	
Mass multiplier:	
RPM constraint:	
Limit [RPM/s]:	
Water properties	
Water type:	Salt
Density:	1026,00 kg/m3
Viscosity:	1,18920e-6 m2/s

Prediction method check [Holtrop]

Parameters	FN [design]	CP	LWL/BWL	BWL/T
Value	0,19	0,76	6,39	3,76
Range	0,06··0,80	0,55··0,85	3,90··14,90	2,10··4,00

Prediction results [System]

	HULL-PROPULSOR				ENGINE			
SPEED [kt]	PETOTAL [kW]	WFT	THD	EFFR	RPMENG [RPM]	PBPROP [kW]	FUEL [L/h]	LOADENG [%]
3,00 !	90,7	0,1658	0,1758	1,0097	114	77,6	---	0,0
5,00 !	395,8	0,1658	0,1758	1,0097	188	338,3	---	0,0
8,00	1515,5	0,1649	0,1758	1,0097	296	1296,2	---	0,0
12,00	4794,0	0,1642	0,1758	1,0097	439	4106,7	---	0,0
15,00	9139,6	0,1638	0,1758	1,0097	546	7837,2	---	0,0
16,00	11113,8	0,1637	0,1758	1,0097	583	9530,8	---	0,0
17,50	14769,1	0,1636	0,1758	1,0097	640	12663,2	---	0,0
18,50	17789,7	0,1635	0,1758	1,0097	679	15249,1	---	0,0
+ 19,50 +	21393,9	0,1634	0,1758	1,0097	719	18334,4	---	0,0
20,00	23453,3	0,1633	0,1758	1,0097	740	20097,9	---	0,0

	POWER DELIVERY							
SPEED [kt]	RPMPROP [RPM]	QPROP [kN·m]	QENG [kN·m]	PDPROP [kW]	PSPROP [kW]	PSTOTAL [kW]	PBTOTAL [kW]	TRANSP
3,00 !	15	46,29	6,17	73,0	75,3	150,6	155,2	---
5,00 !	25	122,62	16,35	318,3	328,2	656,3	676,6	---
8,00	40	297,60	39,68	1219,6	1257,4	2514,7	2592,5	---
12,00	59	636,49	84,87	3864,0	3983,5	7967,0	8213,4	776,7
15,00	73	976,12	130,15	7374,1	7602,1	15204,2	15674,5	508,8
16,00	78	1112,35	148,31	8967,6	9244,9	18489,8	19061,7	446,2
17,50	85	1347,00	179,60	11914,8	12283,3	24566,6	25326,4	367,3
18,50	91	1528,42	203,79	14347,9	14791,7	29583,3	30498,3	322,5
+ 19,50 +	96	1734,05	231,21	17250,8	17784,4	35568,7	36668,8	282,7
20,00	99	1847,28	246,30	18910,1	19494,9	38989,8	40195,7	264,5

	EFFICIENCY				THRUST	
SPEED [kt]	EFFO	EFFG	EFFOA	MERIT	THRPROP [kN]	DELTHR [kN]
3,00 !	0,6223	0,9700	0,6021	0,40179	35,64	58,74
5,00 !	0,6232	0,9700	0,6030	0,39071	93,34	153,86
8,00	0,6235	0,9700	0,6027	0,37758	223,40	368,24
12,00	0,6231	0,9700	0,6017	0,36498	471,12	776,56
15,00	0,6227	0,9700	0,6011	0,36023	718,54	1184,40
16,00	0,6228	0,9700	0,6011	0,36055	819,14	1350,21
17,50	0,6230	0,9700	0,6012	0,36343	995,25	1640,50
18,50	0,6232	0,9700	0,6013	0,36706	1134,00	1869,20
+ 19,50 +	0,6234	0,9700	0,6015	0,37205	1293,82	2132,64
20,00	0,6235	0,9700	0,6015	0,37506	1382,90	2279,47

Propulsion

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Prediction results [Propulsor]

	PROPULSOR COEFS								
SPEED [kt]	J	KT	KQ	KTJ2	KQJ3	CTH	CP	RNPROP	
3,00 !	0,6349	0,1320	0,02143	0,32739	0,083728	0,83369	1,3268	1,19e7	
5,00 !	0,6430	0,1276	0,02096	0,30872	0,078842	0,78614	1,2494	1,95e7	
8,00	0,6523	0,1226	0,02041	0,28801	0,073516	0,73342	1,165	3,09e7	
12,00	0,6611	0,1178	0,01989	0,26948	0,068834	0,68623	1,0908	4,58e7	
15,00	0,6644	0,1160	0,01970	0,26281	0,067168	0,66925	1,0644	5,70e7	
16,00	0,6642	0,1161	0,01971	0,26326	0,06728	0,67039	1,0661	6,08e7	
17,50	0,6622	0,1172	0,01983	0,26728	0,068284	0,68063	1,0821	6,67e7	
18,50	0,6597	0,1186	0,01998	0,27245	0,06958	0,6938	1,1026	7,08e7	
+ 19,50 +	0,6562	0,1205	0,02018	0,27973	0,071415	0,71234	1,1317	7,50e7	
20,00	0,6541	0,1216	0,02030	0,2842	0,072548	0,72372	1,1496	7,72e7	
	CAVITATION								
SPEED [kt]	SIGMAV	SIGMAN	SIGMA07R	TIPSPEED [m/s]	MINBAR	PRESS [kPa]	CAVAVG [%]	CAVMAX [%]	PITCHFC [mm]
3,00 !	117,24	47,26	9,02	6,37	0,075	0,72	2,0	2,0	5978,7
5,00 !	42,21	17,45	3,32	10,48	0,102	1,88	2,0	2,0	6009,2
8,00	16,45	7,00	1,33	16,55	0,165	4,49	2,0	2,0	6044,9
12,00	7,30	3,19	0,61	24,52	0,285	9,47	2,0	2,0	6078,7
15,00	4,67	2,06	0,39	30,51	0,405	14,44	2,0	2,0	6091,3
16,00	4,10	1,81	0,34	32,56	0,454	16,46	2,0	2,0	6090,5
17,50	3,43	1,50	0,28	35,72	0,539	20,00	2,0	2,0	6082,8
18,50	3,07	1,33	0,25	37,91	0,607	22,79	2,0	2,0	6073,2
+ 19,50 +	2,76	1,19	0,23	40,18	0,685	26,00	2,0	2,0	6059,8
20,00	2,62	1,12	0,21	41,34	0,728	27,79	2,0	2,0	6051,7

Propulsion

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Project ID
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File name Hélice.hcnc

Hull data

General			Planing		
Configuration:		Monohull	Proj chine length:		0,000 m
Chine type:		Round/multiple	Proj bottom area:		0,0 m2
Length on WL:		275,945 m	LCG fwd TR:	[XCG/LP 0,000]	0,000 m
Max beam on WL:	[LWL/BWL 6,388]	43,200 m	VCG below WL:		0,000 m
Max molded draft:	[BWL/T 3,757]	11,500 m	Aft station (fwd TR):		0,000 m
Displacement:	[CB 0,749]	105379,00 t	Deadrise:		0,00 deg
Wetted surface:	[CS 2,764]	14716,7 m2	Chine beam:		0,000 m
ITTC-78 (CT)			Chine ht below WL:		0,000 m
LCB fwd TR:	[XCB/LWL 0,483]	133,199 m	Fwd station (fwd TR):		0,000 m
LCF fwd TR:	[XCF/LWL 0,455]	125,596 m	Deadrise:		0,00 deg
Max section area:	[CX 0,987]	490,4 m2	Chine beam:		0,000 m
Waterplane area:	[CWP 0,834]	9937,3 m2	Chine ht below WL:		0,000 m
Bulb section area:		47,2 m2	Propulsor type:		Propeller
Bulb ctr below WL:		4,010 m	Max prop diameter:		8000,0 mm
Bulb nose fwd TR:		282,962 m	Shaft angle to WL:		0,00 deg
Imm transom area:	[ATR/AX 0,000]	0,0 m2	Position fwd TR:		0,000 m
Transom beam WL:	[BTR/BWL 0,000]	0,000 m	Position below WL:		0,000 m
Transom immersion:	[TTR/T 0,000]	0,000 m	Transom lift device:		Flap
Half entrance angle:		27,00 deg	Device count:		0
Bow shape factor:	[BTK flow]	-1,0	Span:		0,000 m
Stern shape factor:	[WL flow]	1,0	Chord length:		0,000 m
			Deflection angle:		0,00 deg
			Tow point fwd TR:		0,000 m
			Tow point below WL:		0,000 m

Propulsor data

Propulsor				Propeller options	
Count:		2		Oblique angle corr:	Off
Propulsor type:		Propeller series		Shaft angle to WL:	0,00 deg
Propeller type:		FPP		Added rise of run:	0,00 deg
Propeller series:		B Series		Propeller cup:	0,0 mm
Propeller sizing:		By power		KTKQ corrections:	Standard
Reference prop:				Scale correction:	Full ITTC
Blade count:		6		KT multiplier:	1,000
Expanded area ratio:		0,9900	[Keep]	KQ multiplier:	1,000
Propeller diameter:		8000,0 mm	[Size]	Blade T/C [0.7R]:	Standard
Propeller mean pitch:	[P/D 0,8313]	6650,0 mm	[Keep]	Roughness:	Standard
Hub immersion:		6,9 mm		Cav breakdown:	Off
Engine/gear				**Design condition**	
Engine data:				Max prop diam:	8000,0 mm
Rated RPM:		0 RPM		Design speed:	19,50 kt
Rated power:		0,0 kW		Reference power:	44000,0 kW
Gear efficiency:		0,970		Design point:	0,850
Load correction:		Off		Reference RPM:	600,0
Gear ratio:		7,500	[Keep]	Design point:	1,000
Shaft efficiency:		0,970			

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Description
File name Hélice.hcnc

Symbols and values

SPEED = Vessel speed

PETOTAL = Total vessel effective power
WFT = Taylor wake fraction coefficient
THD = Thrust deduction coefficient
EFFR = Relative-rotative efficiency

RPMENG = Engine RPM
PBPROP = Brake power per propulsor
FUEL = Fuel rate per engine
LOADENG = Percentage of engine max available power at given RPM

RPMPROP = Propulsor RPM
QPROP = Propulsor open water torque
QENG = Engine torque
PDPROP = Delivered power per propulsor
PSPROP = Shaft power per propulsor
PSTOTAL = Total vessel shaft power
PBTOTAL = Total vessel brake power
TRANSP = Transport factor

EFFO = Propulsor open-water efficiency
EFFG = Gear efficiency (load corrected)
EFFOA = Overall propulsion efficiency [=PETOTAL/PSTOTAL]
MERIT = Propulsor merit coefficient

THRPROP = Open-water thrust per propulsor
DELTHR = Total vessel delivered thrust

J = Propulsor advance coefficient
KT = Propulsor thrust coefficient [horizontal, if in oblique flow]
KQ = Propulsor torque coefficient
KTJ2 = Propulsor thrust loading ratio
KQJ3 = Propulsor torque loading ratio
CTH = Horizontal component of bare-hull resistance coefficient
CP = Propulsor thrust loading coefficient
RNPROP = Propeller Reynolds number at 0.7R

SIGMAV = Cavitation number of propeller by vessel speed
SIGMAN = Cavitation number of propeller by RPM
SIGMA07R = Cavitation number of blade section at 0.7R
TIPSPEED = Propeller circumferential tip speed
MINBAR = Minimum expanded blade area ratio recommended by selected cavitation criteria
PRESS = Average propeller loading pressure
CAVAVG = Average predicted back cavitation percentage
CAVMAX = Peak predicted back cavitation percentage [if in oblique flow]
PITCHFC = Minimum recommended pitch to avoid face cavitation

+ = Design speed indicator
* = Exceeds recommended parameter limit
! = Exceeds recommended cavitation criteria [warning]
!! = Substantially exceeds recommended cavitation criteria [critical]
!!! = Thrust breakdown is indicated [severe]
--- = Insignificant or not applicable