Escola Politécnica Superior
UNIVERSIDADE DA CORUÑA

LNG TANKER 160.000m^3
NÚMERO 17-05

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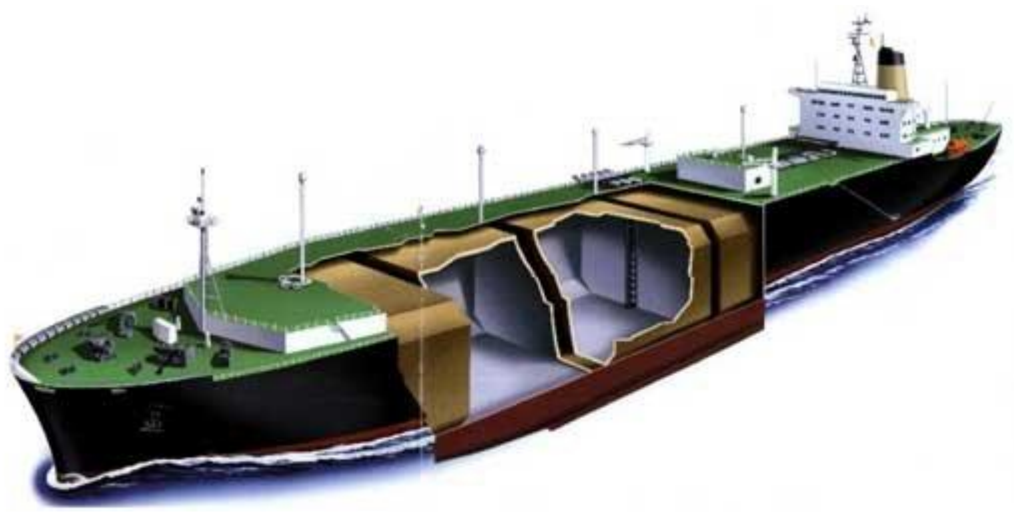
CUADERNO 6

PREDICCIÓN DE POTENCIA. DISEÑO DE PRPULSOR Y TIMÓN



Escola Politécnica Superior
UNIVERSIDADE DA CORUÑA

GRADO EN INGENIERÍA NAVAL Y OCEÁNICA

TRABAJO FIN DE GRADO

CURSO 2.017-2018

PROYECTO NÚMERO 17/05

TIPO DE BUQUE: LNG carrier.

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

CARACTERÍSTICAS DE LA CARGA: LNG con una capacidad de 160.000 m^3.

VELOCIDAD Y AUTONOMÍA: 19.5 knots a velocidad de servicio, al 85% MCR + 15% MM y 5000 millas de autonomía.

SISTEMAS Y EQUIPOS DE CARGA / DESCARGA: bombas de carga y de vapor habituales en buques de este tipo.

PROPULSIÓN: dual-fuel diesel-electric (DFDE)

TRIPULACIÓN Y PASAJE: capacidad para 40 tripulantes en camarotes dobles e individuales.

OTROS EQUIPOS E INSTALACIONES: los habituales en este tipo de buques.

Ferrol, 18 Setiembre 2017

ALUMNA: Dª Carmen Seoane Fernández

ÍNDICE

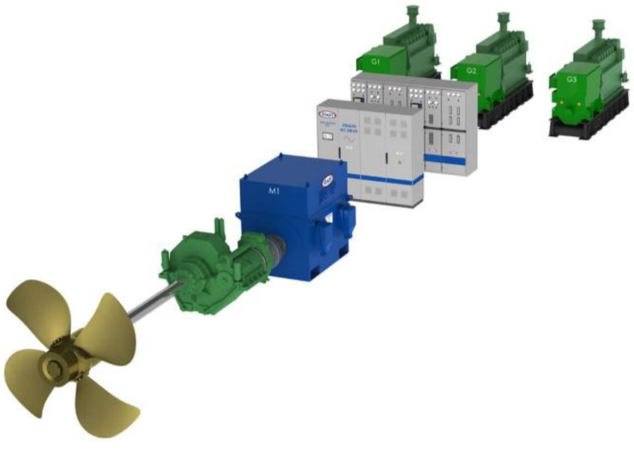
1. INTRODUCCIÓN.

En este cuaderno se hará la predicción de potencia propulsora final así como se diseñará la hélice y el timón. Se muestra una tabla resumen con los datos que se han obtenido en los cuadernos anteriores.

Lpp (m)	271,3
B (m)	45,4
D (m)	26,4
T (m)	12,3
Δ (t)	119484,5
LBD (m3)	324.682,40
Cb	0,767
Cm	0,992
Cp	0,774
V (kn)	19,5

Tabla 1 Características principales

Se calculará la potencia necesaria para la propulsión del buque utilizando el software de Navcad. Con este resultado se escogerá el motor eléctrico que accionará la hélice y teniendo en cuenta el resto de consumidores se comprobará la elección de los motores generadores. El buque llevará cuatro motores generadores, mediante transformadores llevarán la potencia producida a un motor eléctrico que mediante una reductora se la transmitirá a la hélice. Se muestra un esquema de este tipo de propulsión,



La estimación de potencia se hará tomando los datos de la condición de carga 1, saliendo del puerto (100% consumos) y a plena carga. Se muestra una tabla con los resultados para dicha condición de carga obtenidas en las curvas hidrostáticas (Cuaderno 5).

Draft Amidships m	12,663
Displacement t	118826
Heel deg	0,0
Draft at FP m	11,930
Draft at AP m	13,396
Draft at LCF m	12,667
Trim (+ve by stern) m	1,466
WL Length m	275,708
Beam max extents on WL m	45,400
Wetted Area m^2	15142,251
Waterpl. Area m^2	10257,669
Prismatic coeff. (Cp)	0,751
Block coeff. (Cb)	0,695
Max Sect. area coeff. (Cm)	0,972
Waterpl. area coeff. (Cwp)	0,819
LCB from zero pt. (+ve fwd) m	141,191
LCF from zero pt. (+ve fwd) m	134,967
KB m	6,629
KG fluid m	17,985
BMt m	12,675
BML m	414,648
GMt corrected m	1,318
GML m	403,292
KMt m	19,303
KML m	421,271
Immersion (TPc) tonne/cm	105,141
MTc tonne.m	1766,371
RM at 1deg = GMt.Disp.sin(1) tonne.m	2733,697
Max deck inclination deg	0,3095
Trim angle (+ve by stern) deg	0,3095

Tabla 2 Hidrostáticas condición PLENA CARGA

2. CÁLCULO DE LA POTENCIA PROPULSORA.

A partir de la resistencia total al avance del buque se calcula la potencia efectiva,

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

Con la potencia efectiva y teniendo en cuenta el rendimiento total de propulsión se puede calcular la potencia al freno BHP.

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

$$\eta_P = \eta_h \eta_o \eta_{rr} \eta_m$$

Siendo,

η_h El rendimiento del casco, se escribe en función del coeficiente de succión t y el coeficiente de estela w.

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

η_o El rendimiento del propulsor en aguas libres, dato que se obtiene en este caso a partir del cálculo d navcad.

η_{rr} El rendimiento rotativo relativo, dato que se obtiene en este caso a partir del cálculo d navcad.

η_m El rendimiento mecánico, este dato tiene en cuenta las pérdidas por rozamiento en la máquina de propulsión (cilindros, bielas…)

La máquina propulsora a la salida entrega BHP (nos interesa hasta aquí). Al trasmitirse por el eje para llegar a la hélice también se producirán pérdidas. Se considera la potencia en el eje SHP. A la hélice se le entrega una potencia algo menor que la del eje, es la potencia entregada a la hélice DHP y por último se considera la potencia de empuje que genera la hélice con la potencia que ha recibido, THP.

Se calculará en este cuaderno y mediante el software de Navcad, la potencia que necesita la hélice y por tanto se obtendrá el motor eléctrico que necesite este buque proyecto. El método de predicción utilizado será el método Holtrop ya que se ajusta a los parámetros del buque proyecto.

Method	Speed	Hull	Details
Holtrop	OK	OK	OK
Andersen	OK	OK	OK
Oortmerssen	OK	Uncertain	OK
Fung (CRTS)	OK	Uncertain	OK
Kostov	OK	Uncertain	OK
BSRA Series (Full)	OK	Uncertain	OK
BSRA Series (Medium)	OK	Uncertain	OK
BSRA Series (Light)	OK	Uncertain	OK
Series 60	OK	Uncertain	OK
Fung (HSTS)	OK	Fail	OK

Ranking: Best Good Fair Poor

Parameters		
FN [design]	0,06··0,34	0,19
CP	0,55··0,85	0,76
LWL/BWL	3,90··14,90	6,13
BWL/T	2,10··4,00	3,55
Lambda	0,01··1,07	0,92

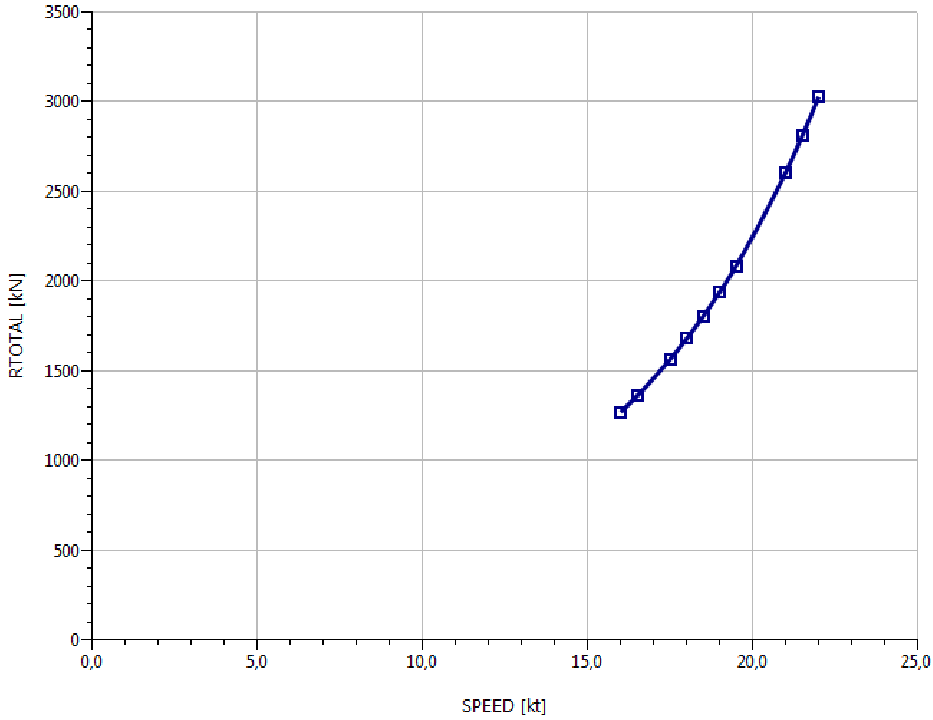
2.1. CÁLCULO DE LA RESISTENCIA AL AVANCE.

En el anexo se muestran todos los resultados obtenidos del Navcad. Se muestran los datos introducidos en el software a partir del plano de formas de datos relacionados con el bulbo, con el casco y con el timón.

ITTC-78 (CT)	
LCB fwd TR:[XCB/LWL 0,560]	**154,398 m**
LCF fwd TR:[XCF/LWL 0,440]	**121,312 m**
Max section area:[CX 0,964]	**549,7 m2**
Waterplane area:[CWP 0,782]	**9704,2 m2**
Bulb section area:	**43,3 m2**
Bulb ctr below WL:	**5,400 m**
Bulb nose fwd TR:	**292,000 m**
Imm transom area:[ATR/AX 0,000]	**0,0 m2**
Transom beam WL:[BTR/BWL 0,000]	**0,000 m**
Transom immersion:[TTR/T 0,000]	**0,000 m**
Half entrance angle:	**35,00 deg**
Bow shape factor:[WL flow]	**1,0**
Stern shape factor:[WL flow]	**1,0**

Rudder	
Count:	**1**
Rudder location:	**Behind propeller**
Type:	**Balanced foil**
Root chord:	**7,300 m**
Tip chord:	**5,950 m**
Span:	**10,800 m**
T/C ratio:	**0,150**
LE sweep:	**0,00 deg**
Projected area:	**71,6 m2**
Wetted surface:	**145,2 m2**

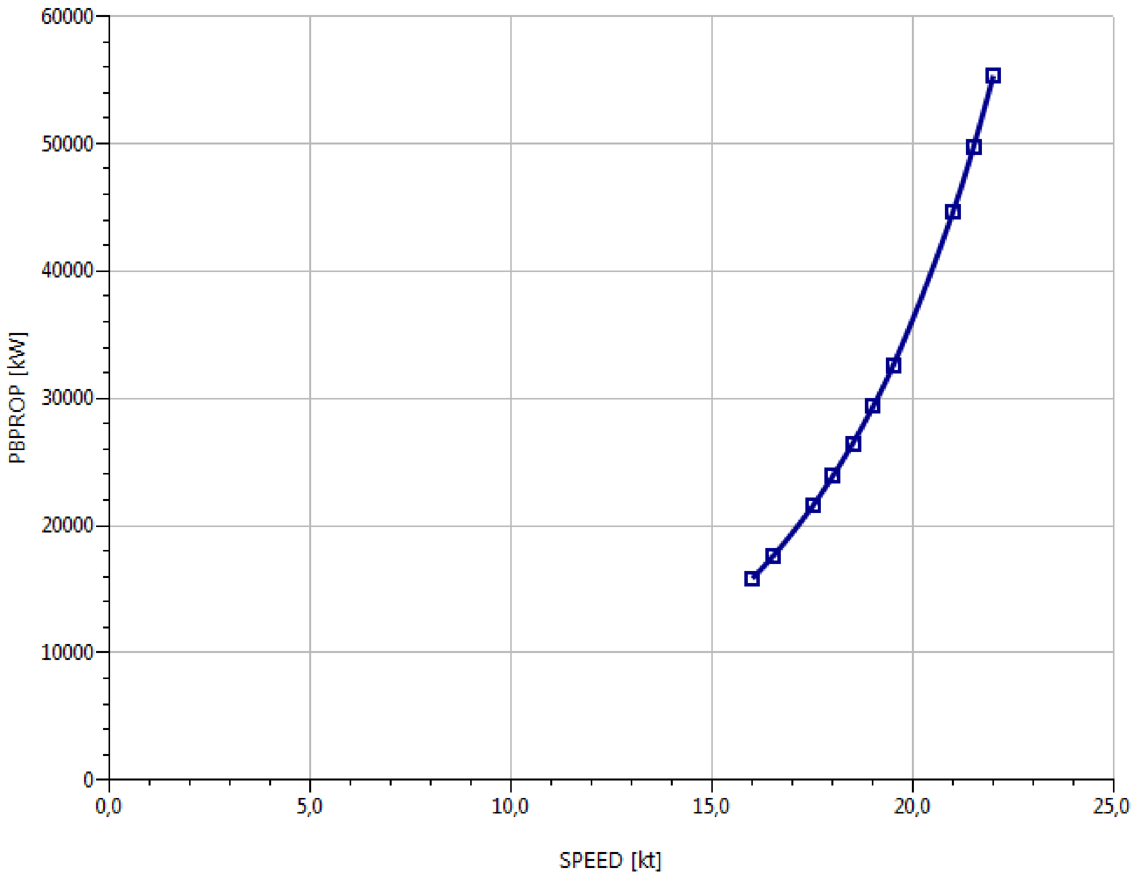
A continuación se muestra una gráfica que representa la resistencia al avance del buque frente a la velocidad.



Para la velocidad de servicio del buque, 19,50 kn, la resistencia al avance será de 2.124,63 kN. El propulsor deberá vencer esa resistencia paraqué el buque avance.

2.2. CÁLCULO DE LA POTENCIA AL FRENO.

Este cálculo nos proporcionará la potencia al freno necesaria para que el buque cumpla con la velocidad de servicio estipulada en la RPA. Este cálculo se realizará por empuje para un propulsor de cuatro palas, con la potencia obtenida se escogerá el motor eléctrico necesario y, con la potencia real que tenga el motor, se diseñarán propulsores de 4, 5 y 6 palas con el fin de obtener un mayor rendimiento. Se muestra una gráfica que representa la potencia al freno frente a la velocidad del buque. Se recuerda que el buque llevará 1 hélice.

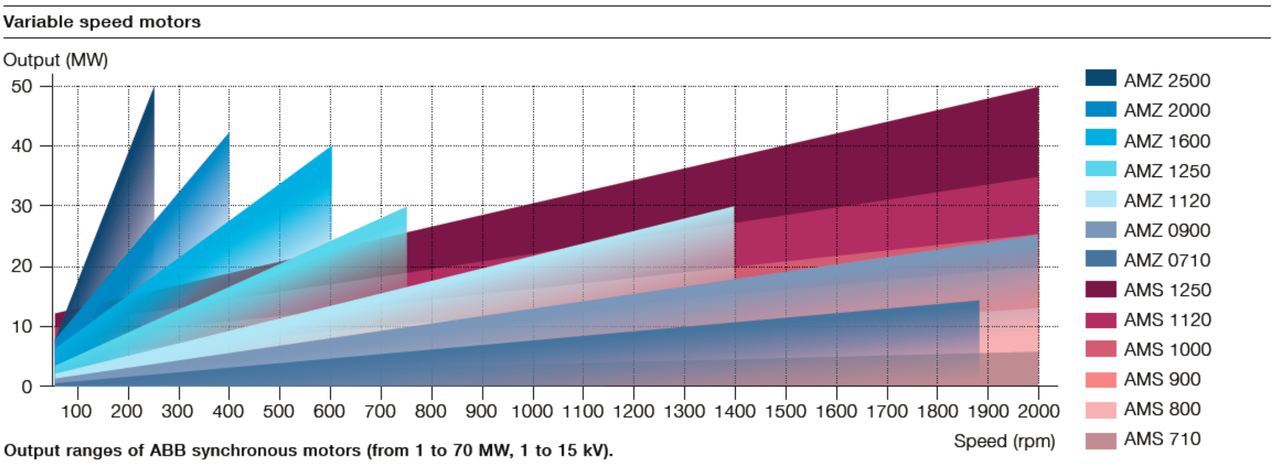


Para la velocidad de servicio de 19,50 kn el buque necesitará 32.090,4 kW. Teniendo en cuenta que en la RPA se ha fijado que el motor irá al 85% MCR la potencia al freno final será de:

$$BHP = \frac{32.090,4}{0,85} = 37.753,4\ kW$$

3. SELECCIÓN DEL MOTOR PROPULSOR.

La propulsión será diesel eléctrica, por tanto el motor que entregará la potencia a la hélice es un motor eléctrico. Después se calculará la potencia total que necesita el buque teniendo en cuenta además de la potencia necesaria para la hélice, la necesaria para los demás consumidores. Para la elección del motor eléctrico se ha utilizado la ficha de los motores ABB.



En el punto anterior se ha estimado la potencia al freno necesaria, por tanto ahora se escogerá el motor eléctrico que necesita el buque para la propulsión.

Por motivos de seguridad se ha decidido instalar dos motores eléctricos para asegurar que si falla uno podremos seguir gobernando el buque. Por tanto, la potencia mínima de cada motor escogido será la mitad de la calculada en el punto anterior. (≈19.000 kW)

Se ha decidido instalas dos motores AMS-1000 que proporciona a 1400 rpm 20.000 kW cada uno. Queda asegurada la potencia que necesita recibir la hélice.

4. CÁLCULO DEL PROPULSOR.

Se utilizará nuevamente el software Navcad pero esta vez el cálculo será por potencia (by power) ya que conocemos las características del motor eléctrico que se utilizará. Se calculará para hélice de 4, 5 y 6 palas y se escogerá el de mayor rendimiento. Los motores eléctricos entregan a 1400 rpm 40.000 kW de potencia por tanto, se utilizará una reductora ya que la hélice trabaja a revoluciones bajas. Se muestra a continuación un resumen de los datos aportados al programa y en el anexo pueden verse los reports completos.

Propulsor data

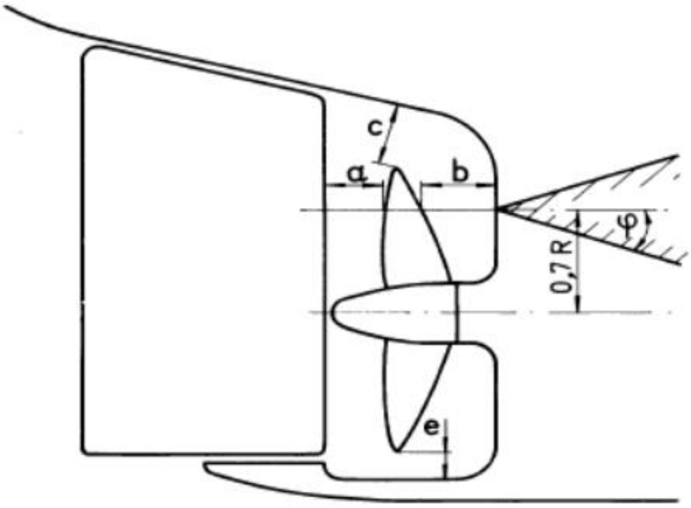
Propulsor				**Propeller options**	
Count:		1		Oblique angle corr:	Off
Propulsor type:		Propeller		Shaft angle to WL:	0,00 deg
Propeller type:		FPP		Added rise of run:	0,00 deg
Propeller series:		B Series		Propeller cup:	0,0 mm
Propeller sizing:		By power		KTKQ corrections:	Custom
Reference prop:				Scale correction:	None
Blade count:		6		KT multiplier:	1,000
Expanded area ratio:		0,8423	[Size]	KQ multiplier:	1,000
Propeller diameter:		9000,0 mm	[Size]	Blade T/C [0.7R]:	0,00
Propeller mean pitch:	[P/D 0,9946]	8951,2 mm	[Size]	Roughness:	0,00 mm
Hub immersion:		6900,0 mm		Cav breakdown:	On
Engine/gear				**Design condition**	
Engine data:		Untitled		Max prop diam:	9000,0 mm
Rated RPM:		1400 RPM		Design speed:	19,50 kt
Rated power:		40000,0 kW		Reference power:	40000,0 kW
Gear efficiency:		0,970		Design point:	0,850
Load correction:		Off		Reference RPM:	600,0
Gear ratio:		8,330	[Size]	Design point:	1,030
Shaft efficiency:		0,970			

PROPULSOR	R.REDUC.	DIÁMETRO	RPM	REND.	BHP	CAV%	LOAD%
4 PALAS	7,27	9	84	0,675	379447,1	4,4	81,3
5 PALAS	7,70	9	79	0,688	37562,4	3,8	79,8
6 PALAS	8,32	9	73	0,690	37422,4	3,7	79,5

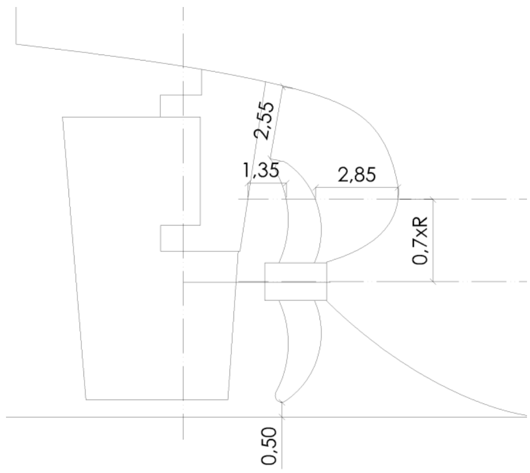
Puede observarse que el propulsor con mayor rendimiento, a menor potencia y menor consumo es el de 6 palas. Para este proyecto se escogerá la hélice de 6 palas, cumpliendo así el objetivo de conseguir el mayor rendimiento. Escogiendo esta hélice se reducirán los problemas por vibraciones ya que también se reduce la cavitación.

5. CLARAS MÍNIMAS PROPULSOR.

El en cuaderno 3 se han calculado las claras mínimas exigidas por el reglamento y a continuación se muestran de nuevo los resultados pero esta vez para una hélice de 6 palas. No habrá problemas con las claras mínimas ya que los valores mínimos disminuyen al aumentar el número de palas. Este cálculo se ha hecho con las exigencias del DNV ya que el reglamento que se ha escogido para este proyecto (Bureau Veritas) no hace referencia a este aspecto.



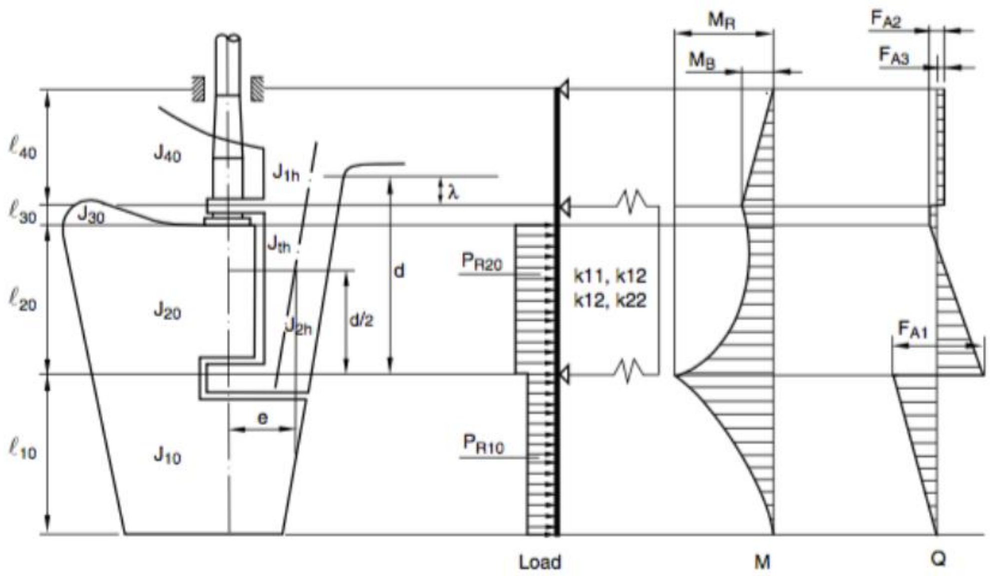
REQUISITO	MÍNIMO
a≥0,2*R	0,9
b≥(0,7-0,04*Z)*R	2,25
c≥(0,48-0,02*Z)*R	1,71
e≥0,07*R	0,32



6. CÁLCULO DEL TIMÓN.

En este apartado se detallarán las características del timón a partir de la Sociedad de Clasificación Bureau Veritas. El timón escogido será un timón semisuspendido y de perfil NACA (tipo 9). Se muestra una imagen de este tipo de timón con su diagrama de cargas obtenida del reglamento.

Figure 9 : Rudder type 9



6.1. CÁLCULO DEL ÁREA Y CUERDA DEL TIMÓN.

El área del timón puede determinarse a partir de un porcentaje del área de deriva ("Proyecto de buques y artefactos"). Para buques de una hélice se estima entre el 1.6 y 1.9 por ciento.

$$A_{TIMON} = 0{,}016 * L_{PP} * T$$

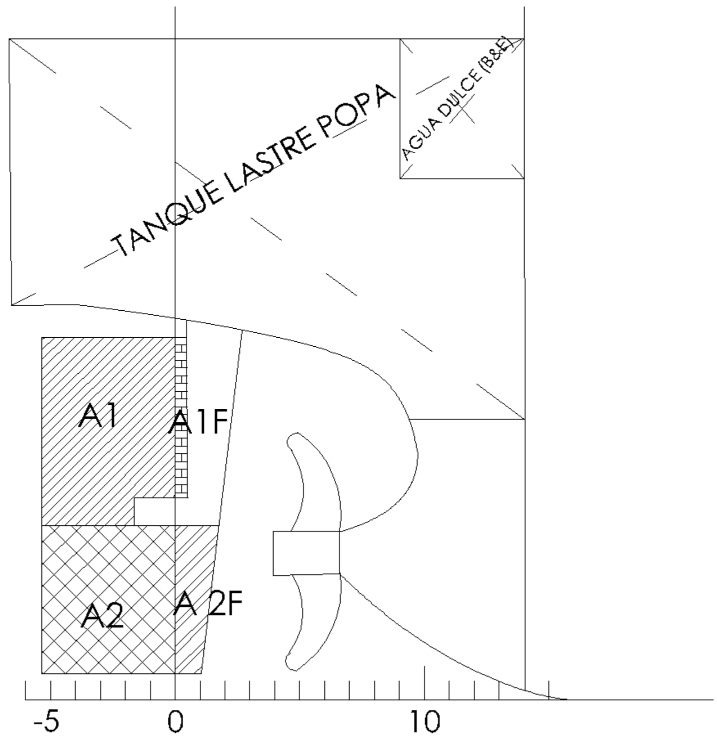
$$A_{TIMON} = 51{,}80\ m^2$$

La cuerda del timón se calcula dividiendo su área entre su altura. Se tomará la altura del timón como 10,8 m.

$$L_{TIMÓN} = \frac{51,80}{10,8}$$

$$L_{TIMÓN} = 4,80\ m$$

Se muestra a continuación un esquema del timón, partiendo su área en cuatro partes como indica el reglamento.



	m²
A1	24,38
A2	20,16
A1F	2,17
A2F	5,36
TOTAL	52,07

El área total diseñada es superior área mínima estimada anteriormente además, se cumple que el área a proa (A1F+A2F) es menor al 20% del área a popa de la mecha (A1+A2).

6.2. CÁLCULO DE LA FUERZA DEL TIMÓN.

Se calculará de acuerdo a Bureau Veritas (parte, Ch.9 Sec.1), incluida en el anexo, que estima la fuerza del timón mediante la siguiente fórmula:

$$C_R = 132 * n_R * A * V^2 * r_1 * r_2 * r_3$$

Siendo estos valores los obtenidos del reglamento.

- n_R el coeficiente de navegación, se tomará 1 debido a que no hay restricciones.
- A el área del timón.
- V la velocidad máxima del buque, 21 kn para avanti y se considerará una velocidad de 10 kn para ciar.
- $r_1 = \frac{\lambda+2}{3}$ el factor de forma y λ un coeficiente que no será menor de 2.
- $\lambda = \frac{h^2}{A}$ siendo h la altura del timón y A el área. λ=2,24
- r_2 coeficiente que depende del perfil escogido. En este caso NACA00

$$r_2 avanti = 1{,}10$$
$$r_2 ciando = 0{,}80$$

- r_3 coeficiente que depende de características de tobera o casco. En este caso se tomará el valor de 1.

La fuerza del timón resultante será:

	AVANTI	CIANDO
n_R	1	1
A	52,07	52,07
V	21	10
r_1	1,41	1,41
r_2	1,1	0,8
r_3	1	1
C_R (kN)	4701,2	775,3

La fórmula utilizada para calcular el par del timón es,

$$M_{TR} = C_R * r$$

Siendo C_R la fuerza calculada anteriormente y r la distancia de la fuerza

- $r = b * \left(\propto - \frac{A_F}{A} \right)$ b es la cuerda del timón y α=0,33 para avanti y α=0,66 para ciar. Af es el área a proa de la mecha, que se ha calculado anteriormente.

El par que provoca el timón será:

	AVANTI	CIANDO
CR (kN)	4053,6	775,3
α	0,33	0,66
r	0,890	2,474
M_{TR} (kN)	3607,1	1918,0

SECTION 1 RUDDERS

Symbols

V_{AV} : Maximum ahead speed, in knots, with the ship on full load waterline; if V_{AV} is less than 10 knots, the maximum service speed is to be taken not less than the value obtained from the following formula:

$$V_{MIN} = \frac{V_{AV} + 20}{3}$$

V_{AD} : Maximum astern speed, in knots, to be taken not less than 0,5 V_{AV}. However, in case the maximum achievable astern speed indicated by the designer is less, the latest can be considered

A : Total area of the rudder blade, in m^2, bounded by the blade external contour, including the mainpiece and the part forward of the centreline of the rudder pintles, if any

k_1 : Material factor, defined in [1.4.1]

k : Material factor, defined in Ch 4, Sec 1, [2.3] (see also [1.4.5])

C_R : Rudder force, in N, acting on the rudder blade, defined in [2.1.1] and [2.2.1]

M_{TR} : Rudder torque, in N.m, acting on the rudder blade, defined in [2.1.2] and [2.2.2]

M_B : Bending moment, in N.m, in the rudder stock, defined in [4.1].

1 General

1.1 Application

1.1.1 Ordinary profile rudders

The requirements of this Section apply to ordinary profile rudders, without any special arrangement for increasing the rudder force, whose maximum orientation at maximum ship speed is limited to 35° on each side.

In general, an orientation greater than 35° is accepted for manoeuvres or navigation at very low speed.

When the maximum orientation at maximum speed is limited to angle smaller than 35° by physical or software devices, the Society may accept reductions, on a case-by-case basis.

1.1.2 High lift profiles

The requirements of this Section also apply to rudders fitted with flaps to increase rudder efficiency. For these rudder types, an orientation at maximum speed less than 35° may be accepted. In these cases, the rudder forces are to be calculated by the Designer for the most severe combinations between orientation angle and ship speed. These calculations are to be considered by the Society on a case-by-case basis.

The rudder scantlings are to be designed so as to be able to sustain possible failures of the orientation control system, or, alternatively, redundancy of the system itself may be required.

1.1.3 Steering nozzles

The requirements for steering nozzles are given in [10].

1.1.4 Special rudder types

Rudders others than those in [1.1.1], [1.1.2] and [1.1.3] will be considered by the Society on a case-by-case basis.

1.1.5 Materials

The requirements of the present section apply to rudders made of steel. Rudders made of other materials are to be considered on a case-by-case basis.

1.2 Gross scantlings

1.2.1 With reference to Ch 4, Sec 2, [1], all scantlings and dimensions referred to in this Section are gross, i.e. they include the margins for corrosion.

1.3 Arrangements

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

1.3.2 Suitable arrangements are to be provided to prevent the rudder from lifting.

In addition, structural rudder stops of suitable strength are to be provided, except where the steering gear is provided with its own rudder stopping devices, as detailed in Pt C, Ch 1, Sec 11.

1.3.3 In rudder trunks which are open to the sea, a seal or stuffing box is to 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. If the top of the rudder trunk is below the deepest waterline two separate stuffing boxes are to be provided.

1.4 Materials

1.4.1 Rudder stocks, pintles, coupling bolts, keys and cast parts of rudders are to be made of rolled steel, steel forgings or steel castings according to the applicable requirements in NR216 Materials, Chapter 2.

1.4.2 The material used for rudder stocks, pintles, keys and bolts is to have a minimum yield stress not less than 200 N/mm².

1.4.3 The requirements relevant to the determination of scantlings contained in this Section apply to steels having a minimum yield stress equal to 235 N/mm².

Where the material used for rudder stocks, pintles, coupling bolts, keys and cast parts of rudders has a yield stress different from 235 N/mm², the scantlings calculated with the formulae contained in the requirements of this Section are to be modified, as indicated, depending on the material factor k_1, to be obtained from the following formula:

$$k_1 = \left(\frac{235}{R_{eH}}\right)^n$$

where:

R_{eH} : Yield stress, in N/mm², of the steel used, and not exceeding the lower of 0,7 R_m and 450 N/mm²

R_m : Minimum ultimate tensile strength, in N/mm² of the steel used,

n : Coefficient to be taken equal to:

- n = 0,75 for $R_{eH} > 235$ N/mm²
- n = 1,00 for $R_{eH} \leq 235$ N/mm².

1.4.4 Significant reductions in rudder stock diameter due to the application of steels with yield stresses greater than 235 N/mm² may be accepted by the Society subject to the results of a check calculation of the rudder stock deformations.

Large rudder stock deformations are to be avoided in order to avoid excessive edge pressures in way of bearings.

1.4.5 Welded parts of rudders are to be made of approved rolled hull materials. For these members, the material factor k defined in Ch 4, Sec 1, [2.3] is to be used.

2 Force and torque acting on the rudder

2.1 Rudder blade without cut-outs

2.1.1 Rudder blade description

A rudder blade without cut-outs may have trapezoidal or rectangular contour.

2.1.2 Rudder force

The rudder force C_R is to be obtained, in N, from the following formula:

$$C_R = 132\ n_R\ A\ V^2\ r_1\ r_2\ r_3$$

where:

n_R : Navigation coefficient, defined in Tab 1

Table 1 : Navigation coefficient n_R

Navigation notation	Navigation coefficient n_R
Unrestricted navigation	1,00
Coastal area	0,85
Sheltered area	0,75

V : V_{AV} or V_{AD}, depending on the condition under consideration (for high lift profiles, see [1.1.2])

r_1 : Shape factor, to be taken equal to:

$$r_1 = \frac{\lambda + 2}{3}$$

λ : Coefficient, to be taken equal to:

$$\lambda = \frac{h^2}{A_T}$$

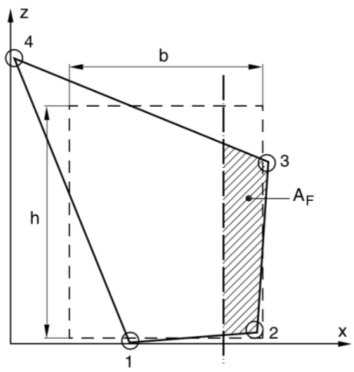
and not greater than 2,0

h : Mean height, in m, of the rudder area to be taken equal to (see Fig 1):

$$h = \frac{z_3 + z_4 - z_2}{2}$$

A_T : Area, in m², to be calculated by adding the rudder blade area A to the area of the rudder post or rudder horn, if any, up to the height h

Figure 1 : Geometry of rudder blade without cut-outs

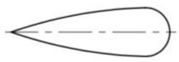
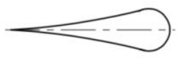
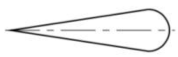
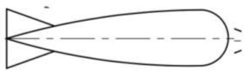
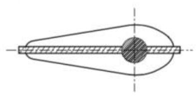


r_2 : Coefficient to be obtained from Tab 2. For other profiles than those defined in Tab 2, the value of r_2 is defined by the Society on a case-by-case basis

r_3 : Coefficient to be taken equal to:

- r_3 = 0,8 for rudders outside the propeller jet (centre rudders on twin screw ships, or similar cases)
- r_3 = 1,15 for rudders behind a fixed propeller nozzle
- r_3 = 1,0 in other cases.

Table 2 : Values of coefficient r_2

Rudder profile type	r_2 for ahead condition	r_2 for astern condition
NACA 00 - Goettingen 	1,10	0,80
Hollow 	1,35	0,90
Flat side 	1,10	0,90
High lift 	1,70	1,30
Fish tail 	1,40	0,80
Single plate 	1,00	1,00

2.1.3 Rudder torque

The rudder torque M_{TR} , for both ahead and astern conditions, is to be obtained, in N.m, from the following formula:

$$M_{TR} = C_R\, r$$

where:

r : Lever of force C_R , in m, equal to:

$$r = b\left(\alpha - \frac{A_F}{A}\right)$$

and to be taken not less than 0,1 b for the ahead condition

b : Mean breadth, in m, of rudder area to be taken equal to (see Fig 1):

$$b = \frac{x_2 + x_3 - x_1}{2}$$

α : Coefficient to be taken equal to:

- α = 0,33 for ahead condition
- α = 0,66 for astern condition

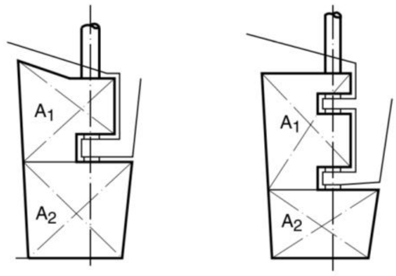
A_F : Area, in m^2, of the rudder blade portion afore the centreline of rudder stock (see Fig 1).

2.2 Rudder blade with cut-outs (semi-spade rudders)

2.2.1 Rudder blade description

A rudder blade with cut-outs may have trapezoidal or rectangular contour, as indicated in Fig 2.

Figure 2 : Rudder blades with cut-outs



Trapezoidal rudder blade Semi-spade rudder with rudder horn - 2 bearings

Trapezoidal rudder blade Semi-spade rudder with rudder horn - 3 bearings

2.2.2 Rudder force

The rudder force C_R , in N, acting on the blade is to be calculated in accordance with [2.1.2].

2.2.3 Rudder torque

The rudder torque M_{TR} , in N·m, is to be calculated in accordance with the following procedure.

The rudder blade area A is to be divided into two rectangular or trapezoidal parts having areas A_1 and A_2, defined in Fig 2, so that:

$$A = A_1 + A_2$$

The rudder forces C_{R1} and C_{R2} , acting on each part A_1 and A_2 of the rudder blade, respectively, are to be obtained, in N, from the following formulae:

$$C_{R1} = C_R \frac{A_1}{A}$$

$$C_{R2} = C_R \frac{A_2}{A}$$

The levers r_1 and r_2 of the forces C_{R1} and C_{R2} , respectively, are to be obtained, in m, from the following formulae:

$$r_1 = b_1\left(\alpha - \frac{A_{1F}}{A_1}\right)$$

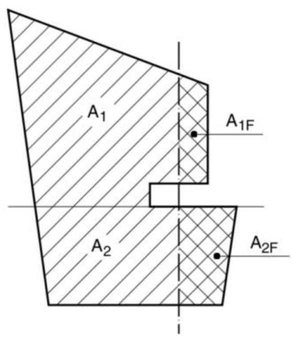
$$r_2 = b_2\left(\alpha - \frac{A_{2F}}{A_2}\right)$$

where:

b_1 , b_2 : Mean breadths of the rudder blade parts having areas A_1 and A_2, respectively, to be determined according to [2.1.3]

A_{1F} , A_{2F} : Areas, in m^2, of the rudder blade parts, defined in Fig 3

Figure 3 : Geometry of rudder blade with cut-outs



α : Coefficient to be taken equal to:

- $\alpha = 0,33$ for ahead condition
- $\alpha = 0,66$ for astern condition

For rudder parts located behind a fixed structure such as a rudder horn, α is to be taken equal to:

- $\alpha = 0,25$ for ahead condition
- $\alpha = 0,55$ for astern condition.

The torques M_{TR1} and M_{TR2} , relevant to the rudder blade parts A_1 and A_2 respectively, are to be obtained, in N.m, from the following formulae:

$M_{TR1} = C_{R1}\, r_1$

$M_{TR2} = C_{R2}\, r_2$

The total torque M_{TR} acting on the rudder stock, for both ahead and astern conditions, is to be obtained, in N.m, from the following formula:

$M_{TR} = M_{TR1} + M_{TR2}$

For the ahead condition only, M_{TR} is to be taken not less than the value obtained, in N.m, from the following formula:

$$M_{TR,MIN} = 0,1\, C_R \frac{A_1 b_1 + A_2 b_2}{A}$$

3 Loads acting on the rudder structure

3.1 General

3.1.1 Loads

The force and torque acting on the rudder, defined in [2], induce in the rudder structure the following loads:

- bending moment and torque in the rudder stock
- support forces
- bending moment, shear force and torque in the rudder body
- bending moment, shear force and torque in rudder horns and solepieces.

3.1.2 Direct load calculations

The bending moment in the rudder stock, the support forces, and the bending moment and shear force in the rudder body are to be determined through direct calculations to be performed in accordance to the static schemes and the load conditions specified in Ch 9, App 1.

For rudders with solepiece or rudder horns these structures are to be included in the calculation model in order to account for the elastic support of the rudder body.

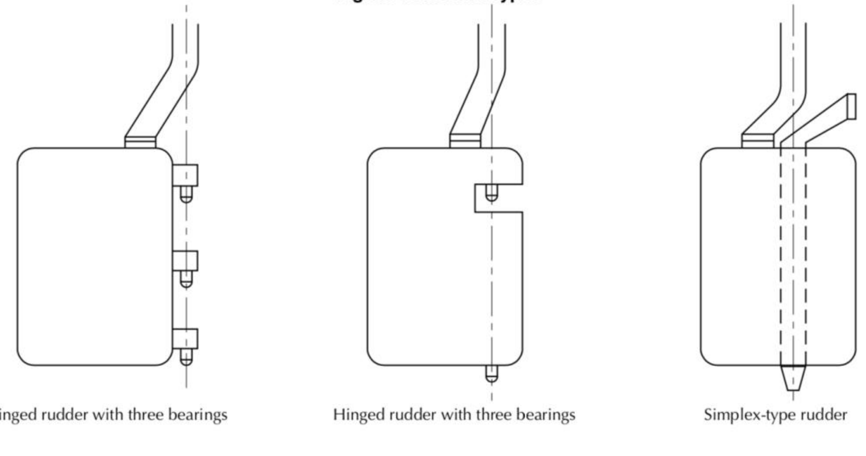
The other loads (i.e. the torque in the rudder stock and in the rudder body and the loads in rudder horns and solepieces) are to be calculated as indicated in the relevant requirements of this Section.

3.1.3 Simplified methods for load calculation

For ordinary rudder types, the bending moment in the rudder stock, the support forces, and the bending moment and shear force in the rudder body may be determined through approximate methods specified in the relevant requirements of this Section.

The other loads (i.e. the torque in the rudder stock and in the rudder body and the loads in rudder horns and solepieces) are to be calculated as indicated in the relevant requirements of this Section.

Figure 4 : Rudder types



ANEXO II. REPORT RESISTENCIA AL AVANCE.

Resistance

26 mar 2018 08:47
HydroComp NavCad 2014

Project ID **LNG**
Descriptio **membrana**
File name **navcad.hcnc**

Analysis

Vessel		ITTC-78 (CT)	Added drag		
Technique:	[Calc]	Prediction	Appendage:	[Calc]	Holtrop
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
Hull form factor:	[On]	1,269	**Water properties**		
Speed corr:	[Off]		Water type:		Salt
Spray drag corr:	[Off]		Density:		1026,00 kg/m3
Corr allowance:		ITTC-78	Viscosity:		1,18920e-6 m2/s
Roughness [mm]:	[On]	0,15			

Prediction method check [Holtrop]

Parameter	FN [design]	CP	LWL/BWL	BWL/T	Lambda
Value	0,19	0,76	6,13	3,55	0,92
Range	0,06··0,34	0,55··0,85	3,90··14,90	2,10··4,0	0,01··1,07

Prediction results

	SPEED COEFS		ITTC-78 COEFS						
SPEED[kt]	FN	FV	RN	CF	[CTLT/CF]	CR	dCF	CA	CT
16,00	0,158	0,376	1,91e9	0,001415	1,269	0,000137	0,000000	0,000241	0,00217
16,50	0,163	0,388	1,97e9	0,001410	1,269	0,000165	0,000000	0,000237	0,00219
17,50	0,173	0,412	2,09e9	0,001400	1,269	0,000236	0,000000	0,000228	0,00224
18,00	0,178	0,424	2,15e9	0,001395	1,269	0,000279	0,000000	0,000224	0,00227
18,50	0,183	0,435	2,21e9	0,001391	1,269	0,000328	0,000000	0,000220	0,00231
19,00	0,188	0,447	2,27e9	0,001386	1,269	0,000382	0,000000	0,000216	0,00235
+ 19,50 +	0,193	0,459	2,33e9	0,001382	1,269	0,000441	0,000000	0,000212	0,00240
21,00	0,208	0,494	2,50e9	0,001370	1,269	0,000657	0,000000	0,000201	0,00259
21,50	0,213	0,506	2,56e9	0,001366	1,269	0,000740	0,000000	0,000197	0,00267
22,00	0,218	0,518	2,62e9	0,001363	1,269	0,000827	0,000000	0,000194	0,00275

	RESISTANCE								
SPEED[kt]	RBARE[kN]	RAPP[kN]	RWIND[kN]	RSEAS[kN]	RCHAN[kN]	RTOWED[kN]	RMARGIN[kN]	RTOTAL[kN]	
16,00	1137,78	19,07	0,00	0,00	0,00	113,78	113,78	1270,63	
16,50	1219,61	20,18	0,00	0,00	0,00	121,96	121,96	1361,76	
17,50	1403,05	22,51	0,00	0,00	0,00	140,30	140,30	1565,86	
18,00	1506,21	23,71	0,00	0,00	0,00	150,62	150,62	1680,54	
18,50	1618,13	24,94	0,00	0,00	0,00	161,81	161,81	1804,88	
19,00	1739,62	26,20	0,00	0,00	0,00	173,96	173,96	1939,79	
+ 19,50 +	1871,63	27,49	0,00	0,00	0,00	187,16	187,16	2086,28	
21,00	2341,58	31,52	0,00	0,00	0,00	234,16	234,16	2607,26	
21,50	2524,55	32,92	0,00	0,00	0,00	252,46	252,46	2809,93	
22,00	2721,27	34,35	0,00	0,00	0,00	272,13	272,13	3027,75	

	EFFECTIVE POWER		OTHER		
SPEED[kt]	PEBARE[kW]	PETOTAL[kW]	CTLR	CTLT	RBARE/W
16,00	9365,2	10458,7	0,00246	0,03897	0,00098
16,50	10352,5	11559,1	0,00297	0,03928	0,00105
17,50	12631,3	14097,1	0,00423	0,04017	0,00120
18,00	13947,5	15561,8	0,00500	0,04076	0,00129
18,50	15400,1	17177,4	0,00587	0,04145	0,00139
19,00	17003,8	18960,3	0,00684	0,04225	0,00149
+ 19,50 +	18775,6	20928,9	0,00791	0,04315	0,00161
21,00	25296,8	28167,1	0,01178	0,04655	0,00201
21,50	27922,9	31079,4	0,01327	0,04788	0,00217
22,00	30798,8	34267,4	0,01482	0,04929	0,00234

Report ID20180326-0847 HydroComp NavCad 2014 14.02.0029.S1002.539

Resistance

26 mar 2018 08:47
HydroComp NavCad 2014

Project ID **LNG**
Description **membrana**
File name **navcad.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:	**275,710 m**	LCG fwd TR:[XCG/LP 0,000]	**0,000 m**
Max beam on WL:[LWL/BWL 6,127]	**45,000 m**	VCG below WL:	**0,000 m**
Max molded draft:[BWL/T 3,552]	**12,670 m**	Aft station (fwd TR):	**0,000 m**
Displacement:[CB 0,737]	**118826,00 t**	Deadrise:	**0,00 deg**
Wetted surface:[CS 2,665]	**15059,2 m2**	Chine beam:	**0,000 m**
ITTC-78 (CT)		Chine ht below WL:	**0,000 m**
LCB fwd TR:[XCB/LWL 0,560]	**154,398 m**	Fwd station (fwd TR):	**0,000 m**
LCF fwd TR:[XCF/LWL 0,440]	**121,312 m**	Deadrise:	**0,00 deg**
Max section area:[CX 0,964]	**549,7 m2**	Chine beam:	**0,000 m**
Waterplane area:[CWP 0,782]	**9704,2 m2**	Chine ht below WL:	**0,000 m**
Bulb section area:	**43,3 m2**	Propulsor type:	**Propeller**
Bulb ctr below WL:	**5,400 m**	Max prop diameter:	**9000,0 mm**
Bulb nose fwd TR:	**292,000 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:	**35,00 deg**	Device count:	**0**
Bow shape factor:[WL 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**

Report ID20180326-0847 HydroComp NavCad 2014 14.02.0029.S1002.539

Resistance

26 mar 2018 08:47
HydroComp NavCad 2014

Project ID **LNG**
Description **membrana**
File name **navcad.hcnc**

Appendage data

General		**Skeg/Keel**	
Definition:	**Component**	Count:	**0**
Percent of hull drag:	**5,00 %**	Type:	**Skeg**
Planing influence		Mean length:	**0,000 m**
LCE fwd TR:	**0,000 m**	Mean width:	**0,000 m**
VCE below WL:	**0,000 m**	Height aft:	**0,000 m**
Shafting		Height mid:	**0,000 m**
Count:	**1**	Height fwd:	**0,000 m**
Max prop diameter:	**9000,0 mm**	Projected area:	**0,0 m2**
Shaft angle to WL:	**0,00 deg**	Wetted surface:	**0,0 m2**
Exposed shaft length:	**0,000 m**	**Stabilizer**	
Shaft diameter:	**0,000 m**	Count:	**0**
Wetted surface:	**0,0 m2**	Root chord:	**0,000 m**
Strut bossing length:	**0,000 m**	Tip chord:	**0,000 m**
Bossing diameter:	**0,000 m**	Span:	**0,000 m**
Wetted surface:	**0,0 m2**	T/C ratio:	**0,000**
Hull bossing length:	**0,000 m**	LE sweep:	**0,00 deg**
Bossing diameter:	**0,000 m**	Wetted surface:	**0,0 m2**
Wetted surface:	**0,0 m2**	Projected area:	**0,0 m2**
Strut (per shaft line)		Dynamic multiplier:	**1,00**
Count:	**0**	**Bilge keel**	
Root chord:	**0,000 m**	Count:	**0**
Tip chord:	**0,000 mm**	Mean length:	**0,000 m**
Span:	**0,000 m**	Mean base width:	**0,000 m**
T/C ratio:	**0,000**	Mean projection:	**0,000 m**
Projected area:	**0,0 m2**	Wetted surface:	**0,0 m2**
Wetted surface:	**0,0 m2**	**Tunnel thruster**	
Exposed palm depth:	**0,000 m**	Count:	**0**
Exposed palm width:	**0,000 m**	Diameter:	**0,000 m**
Rudder		**Sonar dome**	
Count:	**1**	Count:	**0**
Rudder location:	**Behind propeller**	Wetted surface:	**0,0 m2**
Type:	**Balanced foil**	**Miscellaneous**	
Root chord:	**7,300 m**	Count:	**0**
Tip chord:	**5,950 m**	Drag area:	**0,0 m2**
Span:	**10,800 m**	Drag coef:	**0,00**
T/C ratio:	**0,150**		
LE sweep:	**0,00 deg**		
Projected area:	**71,6 m2**		
Wetted surface:	**145,2 m2**		

Environment data

Wind		**Seas**	
Wind speed:	**0,00 kt**	Significant wave ht:	**0,000 m**
Angle off bow:	**0,00 deg**	Modal wave period:	**0,0 sec**
Gradient correction:	**Off**	**Shallow/channel**	
Exposed hull		Water depth:	**0,000 m**
Transverse area:	**0,0 m2**	Type:	**Shallow water**
VCE above WL:	**0,000 m**	Channel width:	**0,000 m**
Profile area:	**0,0 m2**	Channel side slope:	**0,00 deg**
Superstructure		Hull girth:	**0,000 m**
Superstructure shape:	**Cargo ship**		
Transverse area:	**0,0 m2**		
VCE above WL:	**0,000 m**		
Profile area:	**0,0 m2**		

Report ID20180326-0847 HydroComp NavCad 2014 14.02.0029.S1002.539

Resistance

26 mar 2018 08:47
HydroComp NavCad 2014

Project ID **LNG**
Description **membrana**
File name **navcad.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

Report ID20180326-0847 HydroComp NavCad 2014 14.02.0029.S1002.539

ANEXO III. REPORT CÁLCULO POTENCIA POR EMPUJE.

Propulsion

6 abr 2018 04:05
HydroComp NavCad 2014

Project ID **LNG**
Description **membrana**
File name **navcad.hcnc**

Analysis

Hull-propulsor			System analysis	
Technique:	[Calc]	Prediction	Cavitation criteria:	Keller eqn
Prediction:		Holtrop	Analysis type:	Free run
Reference ship:			CPP method:	
Max prop diam:		9000,0 mm	Engine RPM:	
Correction			Mass multiplier:	
Viscous scale corr:	[Off]		RPM constraint:	
Rudder location:			Limit [RPM/s]:	
Friction line:			**Water properties**	
Hull form factor:			Water type:	Salt
Corr allowance:			Density:	1026,00
Roughness [mm]:			Viscosity:	1,18920e-6
Ducted prop corr:	[Off]			
Tunnel stern corr:	[Off]			
Effective diam:				
Recess depth:				

Prediction method check [Holtrop]

Parameters	FN [design]	CP	LWL/BWL	BWL/T
Value	0,19	0,76	6,13	3,55
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[%]
16,00	10678,7	0,3968	0,2107	1,0049	517	15656,0	---	39,1
16,50	11799,1	0,3965	0,2107	1,0049	535	17335,1	---	43,3
17,50	14380,4	0,3960	0,2107	1,0049	571	21251,4	---	53,1
18,00	15868,6	0,3957	0,2107	1,0049	591	23539,6	---	58,8
18,50	17508,9	0,3955	0,2107	1,0049	610	26086,7	---	65,2
19,00	19317,7	0,3953	0,2107	1,0049	631	28924,7	---	72,3
+ 19,50 +	21313,4	0,3951	0,2107	1,0049	652	32090,4	---	80,2
21,00	28641,1	0,3945	0,2107	1,0049	720	44002,2	---	110,0
21,50	31586,0	0,3943	0,2107	1,0049	744	48899,5	---	122,2
22,00	34808,0	0,3941	0,2107	1,0049	769	54399,7	---	136,0

	POWER DELIVERY							
SPEED[kt]	RPMPROP[RPM]	QPROP[kN·m]	QENG[kN·m]	PDPROP[kW]	PSPROP[kW]	PSTOTAL[kW]	PBTOTAL[kW]	TRANSP
16,00	66	2138,47	273,26	14730,7	15186,3	15186,3	15656,0	612,6
16,50	68	2290,12	292,64	16310,6	16815,0	16815,0	17335,1	570,6
17,50	73	2627,88	335,80	19995,5	20613,9	20613,9	21251,4	493,7
18,00	75	2816,61	359,92	22148,4	22833,4	22833,4	23539,6	458,4
18,50	78	3020,44	385,97	24545,0	25304,1	25304,1	26086,7	425,1
19,00	81	3240,75	414,12	27215,2	28056,9	28056,9	28924,7	393,8
+ 19,50 +	83	3479,10	444,57	30193,9	31127,7	31127,7	32090,4	364,3
21,00	92	4320,38	552,08	41401,7	42682,2	42682,2	44002,2	286,1
21,50	95	4645,64	593,64	46009,5	47432,5	47432,5	48899,5	263,6
22,00	98	4999,30	638,83	51184,7	52767,7	52767,7	54399,7	242,4

	EFFICIENCY				THRUST	
SPEED[kt]	EFFO	EFFG	EFFOA	MERIT	THRPROP[kN]	DELTHR[kN]
16,00	0,5513	0,9700	0,7032	0,55721	1643,73	1297,36
16,50	0,5504	0,9700	0,7017	0,55812	1761,15	1390,03
17,50	0,5477	0,9700	0,6976	0,56081	2023,78	1597,33
18,00	0,5458	0,9700	0,6950	0,56261	2171,19	1713,67
18,50	0,5436	0,9700	0,6919	0,5647	2330,88	1839,71
19,00	0,5412	0,9700	0,6885	0,56707	2503,99	1976,35
+ 19,50 +	0,5384	0,9700	0,6847	0,56972	2691,85	2124,62
21,00	0,5281	0,9700	0,6710	0,57914	3358,94	2651,14
21,50	0,5243	0,9700	0,6659	0,58262	3618,16	2855,73
22,00	0,5195	0,9700	0,6596	0,58532	3896,63	3075,52

Propulsion

6 abr 2018 04:05
HydroComp NavCad 2014

Project ID **LNG**
Description **membrana**
File name **navcad.hcnc**

Prediction results [Propulsor]

	PROPULSOR COEFS								
SPEED[kt]	J	KT	KQ	KTJ2	KQJ3	CTH	CP	RNPROP	
16,00	**0,5008**	**0,2012**	**0,02908**	**0,80224**	**0,23159**	**2,0429**	**3,6872**	**6,03e7**	
16,50	**0,4997**	**0,2016**	**0,02913**	**0,80753**	**0,2335**	**2,0564**	**3,7176**	**6,23e7**	
17,50	**0,4965**	**0,2030**	**0,02929**	**0,82354**	**0,23933**	**2,0971**	**3,8104**	**6,66e7**	
18,00	**0,4943**	**0,2039**	**0,02939**	**0,83446**	**0,24332**	**2,1249**	**3,874**	**6,88e7**	
18,50	**0,4918**	**0,2050**	**0,02951**	**0,84741**	**0,24808**	**2,1579**	**3,9498**	**7,11e7**	
19,00	**0,4890**	**0,2062**	**0,02965**	**0,86242**	**0,25364**	**2,1961**	**4,0383**	**7,34e7**	
+ 19,50 +	**0,4858**	**0,2075**	**0,02980**	**0,87955**	**0,26002**	**2,2398**	**4,1399**	**7,59e7**	
21,00	**0,4743**	**0,2124**	**0,03036**	**0,9444**	**0,28459**	**2,4049**	**4,5311**	**8,37e7**	
21,50	**0,4700**	**0,2142**	**0,03056**	**0,9699**	**0,29443**	**2,4698**	**4,6877**	**8,65e7**	
22,00	**0,4653**	**0,2159**	**0,03077**	**0,99698**	**0,30543**	**2,5388**	**4,8629**	**8,94e7**	

	CAVITATION								
SPEED[kt]	SIGMAV	SIGMAN	SIGMA07R	TIPSPEED[m/s]	MINBAR	PRESS[kPa]	CAVAVG[%]	CAVMAX[%]	PITCHFC[mm]
16,00	**13,37**	**3,35**	**0,66**	**31,15**	**0,500**	**41,83**	**2,6**	**2,6**	**6184,2**
16,50	**12,56**	**3,14**	**0,62**	**32,21**	**0,522**	**44,81**	**2,9**	**2,9**	**6179,6**
17,50	**11,14**	**2,75**	**0,54**	**34,41**	**0,569**	**51,50**	**3,7**	**3,7**	**6165,9**
18,00	**10,53**	**2,57**	**0,51**	**35,56**	**0,596**	**55,25**	**4,2**	**4,2**	**6156,8**
18,50	**9,96**	**2,41**	**0,47**	**36,75**	**0,626**	**59,31**	**4,9**	**4,9**	**6146,1**
19,00	**9,43**	**2,26**	**0,44**	**37,98**	**0,657**	**63,72 !**	**5,6**	**5,6**	**6134,0**
+ 19,50 +	**8,95**	**2,11**	**0,42**	**39,25**	**0,691**	**68,50 !!**	**6,5**	**6,5**	**6120,5**
21,00	**7,70**	**1,73**	**0,34**	**43,34**	**0,813**	**85,47 !!**	**10,3**	**10,3**	**6072,1**
21,50	**7,34**	**1,62**	**0,32**	**44,79**	**0,861**	**92,07 !!**	**12,1**	**12,1**	**6054,2**
22,00	**7,01**	**1,52**	**0,30**	**46,30**	**0,911**	**99,15 !!**	**14,2**	**14,2**	**6033,0**

Report ID20180406-1605 HydroComp NavCad 2014 14.02.0029.S1002.539

Propulsion

6 abr 2018 04:05
HydroComp NavCad 2014

Project ID **LNG**
Description **membrana**
File name **navcad.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:	**275,710 m**	LCG fwd TR:[XCG/LP 0,000]	**0,000 m**
Max beam on WL:[LWL/BWL 6,127]	**45,000 m**	VCG below WL:	**0,000 m**
Max molded draft:[BWL/T 3,552]	**12,670 m**	Aft station (fwd TR):	**0,000 m**
Displacement:[CB 0,737]	**118826,00 t**	Deadrise:	**0,00 deg**
Wetted surface:[CS 2,665]	**15059,1 m2**	Chine beam:	**0,000 m**
ITTC-78 (CT)		Chine ht below WL:	**0,000 m**
LCB fwd TR:[XCB/LWL 0,512]	**141,190 m**	Fwd station (fwd TR):	**0,000 m**
LCF fwd TR:[XCF/LWL 0,490]	**134,970 m**	Deadrise:	**0,00 deg**
Max section area:[CX 0,964]	**549,7 m2**	Chine beam:	**0,000 m**
Waterplane area:[CWP 0,782]	**9704,2 m2**	Chine ht below WL:	**0,000 m**
Bulb section area:	**43,3 m2**	Propulsor type:	**Propeller**
Bulb ctr below WL:	**5,400 m**	Max prop diameter:	**9000,0 mm**
Bulb nose fwd TR:	**292,000 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:	**35,00 deg**	Device count:	**0**
Bow shape factor:[WL 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:		**1**		Oblique angle corr:	**Off**
Propulsor type:		**Propeller**		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:	**Custom**
Reference prop:				Scale correction:	**None**
Blade count:		**4**		KT multiplier:	**1,000**
Expanded area ratio:		**0,6177**	**[Size]**	KQ multiplier:	**1,000**
Propeller diameter:		**9000,0 mm**	**[Size]**	Blade T/C [0.7R]:	**0,00**
Propeller mean pitch:	[P/D 0,8632]	**7768,5 mm**	**[Size]**	Roughness:	**0,00 mm**
Hub immersion:		**6900,0 mm**		Cav breakdown:	**On**
Engine/gear				**Design condition**	
Engine data:		**Untitled**		Max prop diam:	**9000,0 mm**
Rated RPM:		**600 RPM**		Design speed:	**19,50 kt**
Rated power:		**40000,0 kW**		Reference power:	**40000,0 kW**
Gear efficiency:		**0,970**		Design point:	**0,850**
Load correction:		**Off**		Reference RPM:	**600,0**
Gear ratio:		**7,826**	**[Size]**	Design point:	**1,030**
Shaft efficiency:		**0,970**			

Report ID20180406-1605 HydroComp NavCad 2014 14.02.0029.S1002.539

Propulsion

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Project ID **LNG**
Description **membrana**
File name **navcad.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

Report ID20180406-1605 HydroComp NavCad 2014 14.02.0029.S1002.539

ANEXO IV. REPORT CÁLCULO PROPULSOR 4 PALAS.

Propulsion

17 may 2018 09:11
HydroComp NavCad 2014

Project ID **LNG**
Description **membrana**
File name **navcad.hcnc**

Analysis

Hull-propulsor		
Technique:	[Calc]	Prediction
Prediction:		Holtrop
Reference ship:		
Max prop diam:		9000,0 mm
Correction		
Viscous scale corr:	[Off]	
Rudder location:		
Friction line:		
Hull form factor:		
Corr allowance:		
Roughness [mm]:		
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
Viscosity:	1,18920e-6

Prediction method check [Holtrop]

Parameters	FN [design]	CP	LWL/BWL	BWL/T
Value	0,19	0,76	6,13	3,55
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[%]
16,00	10678,7	0,3968	0,2107	1,0009	485	15874,9	---	39,7
16,50	11799,1	0,3965	0,2107	1,0009	502	17577,1	---	43,9
17,50	14380,4	0,3960	0,2107	1,0009	536	21546,9	---	53,9
18,00	15868,6	0,3957	0,2107	1,0009	554	23866,0	---	59,7
18,50	17508,9	0,3955	0,2107	1,0009	572	26447,3	---	66,1
19,00	19317,7	0,3953	0,2107	1,0009	591	29323,1	---	73,3
+ 19,50 +	21313,4	0,3951	0,2107	1,0009	611	32530,6	---	81,3
21,00	28641,1	0,3945	0,2107	1,0009	674	44597,6	---	111,5
21,50	31586,0	0,3943	0,2107	1,0009	697	49557,8	---	123,9
22,00	34808,0	0,3941	0,2107	1,0009	720	55047,5	---	137,6

	POWER DELIVERY							
SPEED[kt]	RPMPROP[RPM]	QPROP[kN·m]	QENG[kN·m]	PDPROP[kW]	PSPROP[kW]	PSTOTAL[kW]	PBTOTAL[kW]	TRANSP
16,00	66	2148,83	294,26	14936,7	15398,7	15398,7	15874,9	604,2
16,50	69	2301,26	315,14	16538,3	17049,8	17049,8	17577,1	562,7
17,50	73	2640,82	361,64	20273,4	20900,5	20900,5	21546,9	486,9
18,00	76	2830,59	387,63	22455,5	23150,0	23150,0	23866,0	452,1
18,50	78	3035,58	415,70	24884,3	25653,9	25653,9	26447,3	419,3
19,00	81	3257,16	446,04	27590,1	28443,4	28443,4	29323,1	388,4
+ 19,50 +	84	3496,93	478,88	30608,1	31554,7	31554,7	32530,6	359,3
21,00	92	4343,50	594,81	41961,9	43259,7	43259,7	44597,6	282,3
21,50	95	4670,90	639,64	46628,9	48071,0	48071,0	49557,8	260,1
22,00	99	5021,90	687,71	51794,2	53396,1	53396,1	55047,5	239,6

	EFFICIENCY				THRUST	
SPEED[kt]	EFFO	EFFG	EFFOA	MERIT	THRPROP[kN]	DELTHR[kN]
16,00	0,5459	0,9700	0,6935	0,55174	1643,73	1297,36
16,50	0,5450	0,9700	0,6920	0,55264	1761,15	1390,03
17,50	0,5423	0,9700	0,6880	0,55534	2023,78	1597,33
18,00	0,5405	0,9700	0,6855	0,55714	2171,19	1713,67
18,50	0,5384	0,9700	0,6825	0,55924	2330,88	1839,71
19,00	0,5359	0,9700	0,6792	0,56161	2503,99	1976,34
+ 19,50 +	0,5332	0,9700	0,6754	0,56426	2691,85	2124,62
21,00	0,5232	0,9700	0,6621	0,57371	3358,94	2651,14
21,50	0,5194	0,9700	0,6571	0,57719	3618,16	2855,73
22,00	0,5155	0,9700	0,6519	0,58075	3896,63	3075,52

Propulsion

17 may 2018 09:11
HydroComp NavCad 2014

Project ID **LNG**
Description **membrana**
File name **navcad.hcnc**

Prediction results [Propulsor]

	PROPULSOR COEFS								
SPEED[kt]	J	KT	KQ	KTJ2	KQJ3	CTH	CP	RNPROP	
16,00	**0,4982**	**0,1991**	**0,02893**	**0,80225**	**0,23389**	**2,0429**	**3,7387**	**6,95e7**	
16,50	**0,4972**	**0,1996**	**0,02898**	**0,80753**	**0,23581**	**2,0564**	**3,7695**	**7,19e7**	
17,50	**0,4941**	**0,2010**	**0,02914**	**0,82354**	**0,24168**	**2,0971**	**3,8634**	**7,68e7**	
18,00	**0,4920**	**0,2020**	**0,02925**	**0,83446**	**0,24571**	**2,1249**	**3,9277**	**7,93e7**	
18,50	**0,4895**	**0,2030**	**0,02938**	**0,84741**	**0,25051**	**2,1579**	**4,0044**	**8,19e7**	
19,00	**0,4867**	**0,2043**	**0,02953**	**0,86242**	**0,2561**	**2,1961**	**4,0939**	**8,47e7**	
+ 19,50 +	**0,4836**	**0,2057**	**0,02969**	**0,87955**	**0,26253**	**2,2398**	**4,1967**	**8,75e7**	
21,00	**0,4723**	**0,2107**	**0,03027**	**0,9444**	**0,28729**	**2,4049**	**4,5924**	**9,64e7**	
21,50	**0,4681**	**0,2125**	**0,03049**	**0,9699**	**0,2972**	**2,4698**	**4,7508**	**9,96e7**	
22,00	**0,4638**	**0,2144**	**0,03071**	**0,99698**	**0,30783**	**2,5388**	**4,9208**	**1,03e8**	

	CAVITATION								
SPEED[kt]	SIGMAV	SIGMAN	SIGMA07R	TIPSPEED[m/s]	MINBAR	PRESS[kPa]	CAVAVG[%]	CAVMAX[%]	PITCHFC[mm]
16,00	**13,37**	**3,32**	**0,65**	**31,31**	**0,500**	**36,45**	**2,0**	**2,0**	**6153,1**
16,50	**12,56**	**3,10**	**0,61**	**32,37**	**0,522**	**39,05**	**2,0**	**2,0**	**6148,7**
17,50	**11,14**	**2,72**	**0,54**	**34,58**	**0,569**	**44,87**	**2,5**	**2,5**	**6135,8**
18,00	**10,53**	**2,55**	**0,50**	**35,73**	**0,596**	**48,14**	**2,8**	**2,8**	**6127,2**
18,50	**9,96**	**2,39**	**0,47**	**36,92**	**0,626**	**51,68**	**3,2**	**3,2**	**6117,1**
19,00	**9,43**	**2,23**	**0,44**	**38,15**	**0,657**	**55,52**	**3,7**	**3,7**	**6105,7**
+ 19,50 +	**8,95**	**2,09**	**0,41**	**39,42**	**0,691**	**59,69**	**4,4**	**4,4**	**6093,0**
21,00	**7,70**	**1,72**	**0,34**	**43,51**	**0,813**	**74,48 !!**	**7,1**	**7,1**	**6047,3**
21,50	**7,34**	**1,61**	**0,32**	**44,96**	**0,861**	**80,23 !!**	**8,4**	**8,4**	**6030,4**
22,00	**7,01**	**1,51**	**0,30**	**46,45**	**0,911**	**86,40 !!**	**9,9**	**9,9**	**6013,0**

Report ID20180517-0911 HydroComp NavCad 2014 14.02.0029.S1002.539

Propulsion

17 may 2018 09:11
HydroComp NavCad 2014

Project ID **LNG**
Description **membrana**
File name **navcad.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:	**275,710 m**	LCG fwd TR:[XCG/LP 0,000]	**0,000 m**
Max beam on WL:[LWL/BWL 6,127]	**45,000 m**	VCG below WL:	**0,000 m**
Max molded draft:[BWL/T 3,552]	**12,670 m**	Aft station (fwd TR):	**0,000 m**
Displacement:[CB 0,737]	**118826,00 t**	Deadrise:	**0,00 deg**
Wetted surface:[CS 2,665]	**15059,1 m2**	Chine beam:	**0,000 m**
ITTC-78 (CT)		Chine ht below WL:	**0,000 m**
LCB fwd TR:[XCB/LWL 0,512]	**141,190 m**	Fwd station (fwd TR):	**0,000 m**
LCF fwd TR:[XCF/LWL 0,490]	**134,970 m**	Deadrise:	**0,00 deg**
Max section area:[CX 0,964]	**549,7 m2**	Chine beam:	**0,000 m**
Waterplane area:[CWP 0,782]	**9704,2 m2**	Chine ht below WL:	**0,000 m**
Bulb section area:	**43,3 m2**	Propulsor type:	**Propeller**
Bulb ctr below WL:	**5,400 m**	Max prop diameter:	**9000,0 mm**
Bulb nose fwd TR:	**292,000 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:	**35,00 deg**	Device count:	**0**
Bow shape factor:[WL 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:		**1**		Oblique angle corr:	**Off**
Propulsor type:		**Propeller**		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:	**Custom**
Reference prop:				Scale correction:	**None**
Blade count:		**4**		KT multiplier:	**1,000**
Expanded area ratio:		**0,7089**	**[Size]**	KQ multiplier:	**1,000**
Propeller diameter:		**9000,0 mm**	**[Size]**	Blade T/C [0.7R]:	**0,00**
Propeller mean pitch:	[P/D 0,8574]	**7716,9 mm**	**[Size]**	Roughness:	**0,00 mm**
Hub immersion:		**6900,0 mm**		Cav breakdown:	**On**
Engine/gear				**Design condition**	
Engine data:		**Untitled**		Max prop diam:	**9000,0 mm**
Rated RPM:		**1400 RPM**		Design speed:	**19,50 kt**
Rated power:		**40000,0 kW**		Reference power:	**40000,0 kW**
Gear efficiency:		**0,970**		Design point:	**0,850**
Load correction:		**Off**		Reference RPM:	**600,0**
Gear ratio:		**7,302**	**[Size]**	Design point:	**1,030**
Shaft efficiency:		**0,970**			

Report ID20180517-0911 HydroComp NavCad 2014 14.02.0029.S1002.539

Propulsion

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Project ID **LNG**
Description **membrana**
File name **navcad.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

Report ID20180517-0911 HydroComp NavCad 2014 14.02.0029.S1002.539

ANEXO V. REPORT CÁLCULO PROPULSOR 5 PALAS.

Propulsion

17 may 2018 09:10
HydroComp NavCad 2014

Project ID **LNG**
Description **membrana**
File name **navcad.hcnc**

Analysis

Hull-propulsor			**System analysis**	
Technique:	[Calc]	Prediction	Cavitation criteria:	Keller eqn
Prediction:		Holtrop	Analysis type:	Free run
Reference ship:			CPP method:	
Max prop diam:		9000,0 mm	Engine RPM:	
Correction			Mass multiplier:	
Viscous scale corr:	[Off]		RPM constraint:	
Rudder location:			Limit [RPM/s]:	
Friction line:			**Water properties**	
Hull form factor:			Water type:	Salt
Corr allowance:			Density:	1026,00
Roughness [mm]:			Viscosity:	1,18920e-6
Ducted prop corr:	[Off]			
Tunnel stern corr:	[Off]			
Effective diam:				
Recess depth:				

Prediction method check [Holtrop]

Parameters	FN [design]	CP	LWL/BWL	BWL/T
Value	0,19	0,76	6,13	3,55
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[%]
16,00	10678,7	0,3968	0,2107	1,0050	483	15583,5	---	39,0
16,50	11799,1	0,3965	0,2107	1,0050	499	17254,3	---	43,1
17,50	14380,4	0,3960	0,2107	1,0050	533	21150,3	---	52,9
18,00	15868,6	0,3957	0,2107	1,0050	551	23426,1	---	58,6
18,50	17508,9	0,3955	0,2107	1,0050	569	25959,3	---	64,9
19,00	19317,7	0,3953	0,2107	1,0050	588	28781,2	---	72,0
+ 19,50 +	21313,4	0,3951	0,2107	1,0050	608	31928,4	---	79,8
21,00	28641,1	0,3945	0,2107	1,0050	671	43767,1	---	109,4
21,50	31586,0	0,3943	0,2107	1,0050	693	48632,9	---	121,6
22,00	34808,0	0,3941	0,2107	1,0050	716	54018,1	---	135,0

	POWER DELIVERY							
SPEED[kt]	RPMPROP[RPM]	QPROP[kN·m]	QENG[kN·m]	PDPROP[kW]	PSPROP[kW]	PSTOTAL[kW]	PBTOTAL[kW]	TRANSP
16,00	62	2257,31	291,49	14662,5	15116,0	15116,0	15583,5	615,5
16,50	64	2417,42	312,16	16234,6	16736,7	16736,7	17254,3	573,3
17,50	69	2774,00	358,21	19900,4	20515,8	20515,8	21150,3	496,0
18,00	71	2973,26	383,94	22041,7	22723,4	22723,4	23426,1	460,6
18,50	74	3188,49	411,73	24425,1	25180,5	25180,5	25959,3	427,2
19,00	76	3421,13	441,77	27080,2	27917,8	27917,8	28781,2	395,7
+ 19,50 +	79	3672,82	474,27	30041,4	30970,6	30970,6	31928,4	366,1
21,00	87	4561,35	589,01	41180,4	42454,1	42454,1	43767,1	287,6
21,50	90	4904,92	633,37	45758,7	47173,9	47173,9	48632,9	265,0
22,00	93	5273,22	680,93	50825,6	52397,5	52397,5	54018,1	244,1

	EFFICIENCY				THRUST	
SPEED[kt]	EFFO	EFFG	EFFOA	MERIT	THRPROP[kN]	DELTHR[kN]
16,00	0,5538	0,9700	0,7065	0,55975	1643,73	1297,36
16,50	0,5529	0,9700	0,7050	0,56068	1761,15	1390,04
17,50	0,5502	0,9700	0,7009	0,56344	2023,78	1597,32
18,00	0,5484	0,9700	0,6983	0,56528	2171,18	1713,66
18,50	0,5463	0,9700	0,6953	0,56742	2330,87	1839,71
19,00	0,5438	0,9700	0,6920	0,56985	2504,00	1976,35
+ 19,50 +	0,5410	0,9700	0,6882	0,57255	2691,85	2124,62
21,00	0,5309	0,9700	0,6746	0,5822	3358,95	2651,14
21,50	0,5271	0,9700	0,6696	0,58576	3618,15	2855,73
22,00	0,5231	0,9700	0,6643	0,5894	3896,62	3075,52

Propulsion

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HydroComp NavCad 2014

Project ID **LNG**
Description **membrana**
File name **navcad.hcnc**

Prediction results [Propulsor]

	PROPULSOR COEFS								
SPEED[kt]	J	KT	KQ	KTJ2	KQJ3	CTH	CP	RNPROP	
16,00	**0,5310**	**0,2262**	**0,03451**	**0,80224**	**0,23053**	**2,0429**	**3,6701**	**5,75e7**	
16,50	**0,5299**	**0,2267**	**0,03458**	**0,80753**	**0,23243**	**2,0564**	**3,7003**	**5,94e7**	
17,50	**0,5265**	**0,2283**	**0,03477**	**0,82354**	**0,23821**	**2,0971**	**3,7923**	**6,35e7**	
18,00	**0,5243**	**0,2294**	**0,03490**	**0,83445**	**0,24217**	**2,1249**	**3,8553**	**6,56e7**	
18,50	**0,5217**	**0,2306**	**0,03505**	**0,84741**	**0,24689**	**2,1579**	**3,9305**	**6,77e7**	
19,00	**0,5187**	**0,2320**	**0,03522**	**0,86242**	**0,2524**	**2,1961**	**4,0182**	**7,00e7**	
+ 19,50 +	**0,5154**	**0,2336**	**0,03542**	**0,87955**	**0,25873**	**2,2398**	**4,119**	**7,23e7**	
21,00	**0,5033**	**0,2393**	**0,03610**	**0,9444**	**0,2831**	**2,4049**	**4,5069**	**7,97e7**	
21,50	**0,4989**	**0,2414**	**0,03636**	**0,96989**	**0,29285**	**2,4698**	**4,6621**	**8,23e7**	
22,00	**0,4942**	**0,2435**	**0,03662**	**0,99698**	**0,30332**	**2,5388**	**4,8288**	**8,50e7**	

	CAVITATION								
SPEED[kt]	SIGMAV	SIGMAN	SIGMA07R	TIPSPEED[m/s]	MINBAR	PRESS[kPa]	CAVAVG[%]	CAVMAX[%]	PITCHFC[mm]
16,00	**13,37**	**3,77**	**0,74**	**29,38**	**0,536**	**33,19**	**2,0**	**2,0**	**6557,6**
16,50	**12,56**	**3,53**	**0,69**	**30,37**	**0,560**	**35,56**	**2,0**	**2,0**	**6553,0**
17,50	**11,14**	**3,09**	**0,60**	**32,44**	**0,614**	**40,86**	**2,2**	**2,2**	**6539,3**
18,00	**10,53**	**2,89**	**0,57**	**33,53**	**0,644**	**43,84**	**2,5**	**2,5**	**6530,1**
18,50	**9,96**	**2,71**	**0,53**	**34,65**	**0,677**	**47,06**	**2,9**	**2,9**	**6519,3**
19,00	**9,43**	**2,54**	**0,50**	**35,80**	**0,712**	**50,56**	**3,3**	**3,3**	**6507,1**
+ 19,50 +	**8,95**	**2,38**	**0,47**	**36,99**	**0,750**	**54,35**	**3,8**	**3,8**	**6493,5**
21,00	**7,70**	**1,95**	**0,38**	**40,83**	**0,887**	**67,82 !**	**6,1**	**6,1**	**6444,6**
21,50	**7,34**	**1,83**	**0,36**	**42,19**	**0,940**	**73,06 !!**	**7,2**	**7,2**	**6426,5**
22,00	**7,01**	**1,71**	**0,34**	**43,59**	**0,997**	**78,68 !!**	**8,4**	**8,4**	**6407,9**

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Propulsion

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Project ID	**LNG**
Description	**membrana**
File name	**navcad.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:	**275,710 m**	LCG fwd TR:[XCG/LP 0,000]	**0,000 m**
Max beam on WL:[LWL/BWL 6,127]	**45,000 m**	VCG below WL:	**0,000 m**
Max molded draft:[BWL/T 3,552]	**12,670 m**	Aft station (fwd TR):	**0,000 m**
Displacement:[CB 0,737]	**118826,00 t**	Deadrise:	**0,00 deg**
Wetted surface:[CS 2,665]	**15059,1 m2**	Chine beam:	**0,000 m**
ITTC-78 (CT)		Chine ht below WL:	**0,000 m**
LCB fwd TR:[XCB/LWL 0,512]	**141,190 m**	Fwd station (fwd TR):	**0,000 m**
LCF fwd TR:[XCF/LWL 0,490]	**134,970 m**	Deadrise:	**0,00 deg**
Max section area:[CX 0,964]	**549,7 m2**	Chine beam:	**0,000 m**
Waterplane area:[CWP 0,782]	**9704,2 m2**	Chine ht below WL:	**0,000 m**
Bulb section area:	**43,3 m2**	Propulsor type:	**Propeller**
Bulb ctr below WL:	**5,400 m**	Max prop diameter:	**9000,0 mm**
Bulb nose fwd TR:	**292,000 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:	**35,00 deg**	Device count:	**0**
Bow shape factor:[WL 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:		**1**		Oblique angle corr:	**Off**
Propulsor type:		**Propeller**		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:	**Custom**
Reference prop:				Scale correction:	**None**
Blade count:		**5**		KT multiplier:	**1,000**
Expanded area ratio:		**0,7785**	**[Size]**	KQ multiplier:	**1,000**
Propeller diameter:		**9000,0 mm**	**[Size]**	Blade T/C [0.7R]:	**0,00**
Propeller mean pitch:	[P/D 0,9142]	**8227,6 mm**	**[Size]**	Roughness:	**0,00 mm**
Hub immersion:		**6900,0 mm**		Cav breakdown:	**On**
Engine/gear				**Design condition**	
Engine data:		**Untitled**		Max prop diam:	**9000,0 mm**
Rated RPM:		**1400 RPM**		Design speed:	**19,50 kt**
Rated power:		**40000,0 kW**		Reference power:	**40000,0 kW**
Gear efficiency:		**0,970**		Design point:	**0,850**
Load correction:		**Off**		Reference RPM:	**600,0**
Gear ratio:		**7,744**	**[Size]**	Design point:	**1,030**
Shaft efficiency:		**0,970**			

Report ID20180517-0910 HydroComp NavCad 2014 14.02.0029.S1002.539

Propulsion

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HydroComp NavCad 2014

Project ID **LNG**
Description **membrana**
File name **navcad.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

Report ID20180517-0910 HydroComp NavCad 2014 14.02.0029.S1002.539

ANEXO VI. REPORT CÁLCULO PROPULSOR 6 PALAS.

Propulsion

17 may 2018 09:12
HydroComp NavCad 2014

Project ID **LNG**
Description **membrana**
File name **navcad.hcnc**

Analysis

Hull-propulsor		
Technique:	[Calc]	Prediction
Prediction:		Holtrop
Reference ship:		
Max prop diam:		9000,0 mm
Correction		
Viscous scale corr:	[Off]	
Rudder location:		
Friction line:		
Hull form factor:		
Corr allowance:		
Roughness [mm]:		
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
Viscosity:	1,18920e-6

Prediction method check [Holtrop]

Parameters	FN [design]	CP	LWL/BWL	BWL/T
Value	0,19	0,76	6,13	3,55
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[%]
16,00	10678,7	0,3968	0,2107	1,0050	482	15522,3	---	38,8
16,50	11799,1	0,3965	0,2107	1,0050	499	17186,8	---	43,0
17,50	14380,4	0,3960	0,2107	1,0050	533	21068,6	---	52,7
18,00	15868,6	0,3957	0,2107	1,0050	550	23336,2	---	58,3
18,50	17508,9	0,3955	0,2107	1,0050	569	25860,3	---	64,7
19,00	19317,7	0,3953	0,2107	1,0050	588	28672,6	---	71,7
+ 19,50 +	21313,4	0,3951	0,2107	1,0050	607	31809,4	---	79,5
21,00	28641,1	0,3945	0,2107	1,0050	670	43611,3	---	109,0
21,50	31586,0	0,3943	0,2107	1,0050	693	48463,2	---	121,2
22,00	34808,0	0,3941	0,2107	1,0050	716	53832,9	---	134,6

	POWER DELIVERY							
SPEED[kt]	RPMPROP[RPM]	QPROP[kN·m]	QENG[kN·m]	PDPROP[kW]	PSPROP[kW]	PSTOTAL[kW]	PBTOTAL[kW]	TRANSP
16,00	58	2421,64	290,70	14604,9	15056,6	15056,6	15522,3	617,9
16,50	60	2593,40	311,32	16171,0	16671,2	16671,2	17186,8	575,5
17,50	64	2975,96	357,24	19823,4	20436,5	20436,5	21068,6	497,9
18,00	66	3189,73	382,91	21957,1	22636,1	22636,1	23336,2	462,4
18,50	68	3420,63	410,62	24332,0	25084,5	25084,5	25860,3	428,9
19,00	71	3670,22	440,59	26978,0	27812,4	27812,4	28672,6	397,2
+ 19,50 +	73	3940,27	473,00	29929,4	30855,1	30855,1	31809,4	367,5
21,00	80	4893,62	587,45	41033,9	42302,9	42302,9	43611,3	288,7
21,50	83	5262,30	631,71	45599,0	47009,3	47009,3	48463,2	265,9
22,00	86	5657,48	679,14	50651,4	52217,9	52217,9	53832,9	245,0

	EFFICIENCY				THRUST	
SPEED[kt]	EFFO	EFFG	EFFOA	MERIT	THRPROP[kN]	DELTHR[kN]
16,00	0,5560	0,9700	0,7092	0,56196	1643,72	1297,35
16,50	0,5551	0,9700	0,7078	0,56288	1761,15	1390,03
17,50	0,5524	0,9700	0,7037	0,56563	2023,79	1597,33
18,00	0,5505	0,9700	0,7010	0,56746	2171,19	1713,67
18,50	0,5484	0,9700	0,6980	0,56959	2330,87	1839,70
19,00	0,5459	0,9700	0,6946	0,57201	2503,99	1976,34
+ 19,50 +	0,5431	0,9700	0,6908	0,5747	2691,85	2124,62
21,00	0,5328	0,9700	0,6770	0,58428	3358,94	2651,13
21,50	0,5290	0,9700	0,6719	0,58781	3618,16	2855,73
22,00	0,5249	0,9700	0,6666	0,59142	3896,59	3075,49

Propulsion

17 may 2018 09:12
HydroComp NavCad 2014

Project ID **LNG**
Description **membrana**
File name **navcad.hcnc**

Prediction results [Propulsor]

	PROPULSOR COEFS								
SPEED[kt]	J	KT	KQ	KTJ2	KQJ3	CTH	CP	RNPROP	
16,00	**0,5719**	**0,2624**	**0,04295**	**0,80224**	**0,22963**	**2,0429**	**3,6557**	**4,83e7**	
16,50	**0,5707**	**0,2630**	**0,04303**	**0,80753**	**0,23152**	**2,0564**	**3,6858**	**4,99e7**	
17,50	**0,5671**	**0,2648**	**0,04327**	**0,82354**	**0,23729**	**2,0971**	**3,7776**	**5,33e7**	
18,00	**0,5646**	**0,2660**	**0,04343**	**0,83446**	**0,24124**	**2,1249**	**3,8405**	**5,51e7**	
18,50	**0,5618**	**0,2675**	**0,04361**	**0,84741**	**0,24595**	**2,1579**	**3,9156**	**5,69e7**	
19,00	**0,5586**	**0,2691**	**0,04382**	**0,86242**	**0,25145**	**2,1961**	**4,0031**	**5,88e7**	
+ 19,50 +	**0,5550**	**0,2709**	**0,04406**	**0,87955**	**0,25777**	**2,2398**	**4,1036**	**6,07e7**	
21,00	**0,5419**	**0,2774**	**0,04490**	**0,9444**	**0,28209**	**2,4049**	**4,4909**	**6,70e7**	
21,50	**0,5371**	**0,2798**	**0,04521**	**0,96989**	**0,29183**	**2,4698**	**4,6459**	**6,92e7**	
22,00	**0,5321**	**0,2823**	**0,04553**	**0,99697**	**0,30228**	**2,5388**	**4,8122**	**7,14e7**	

	CAVITATION								
SPEED[kt]	SIGMAV	SIGMAN	SIGMA07R	TIPSPEED[m/s]	MINBAR	PRESS[kPa]	CAVAVG[%]	CAVMAX[%]	PITCHFC[mm]
16,00	**13,37**	**4,37**	**0,85**	**27,28**	**0,572**	**30,67**	**2,0**	**2,0**	**7062,7**
16,50	**12,56**	**4,09**	**0,79**	**28,20**	**0,599**	**32,87**	**2,0**	**2,0**	**7057,7**
17,50	**11,14**	**3,58**	**0,69**	**30,13**	**0,658**	**37,77**	**2,2**	**2,2**	**7042,6**
18,00	**10,53**	**3,36**	**0,65**	**31,13**	**0,692**	**40,52**	**2,5**	**2,5**	**7032,5**
18,50	**9,96**	**3,14**	**0,61**	**32,17**	**0,728**	**43,50**	**2,8**	**2,8**	**7020,7**
19,00	**9,43**	**2,94**	**0,57**	**33,24**	**0,767**	**46,73**	**3,2**	**3,2**	**7007,3**
+ 19,50 +	**8,95**	**2,76**	**0,54**	**34,35**	**0,809**	**50,23**	**3,7**	**3,7**	**6992,4**
21,00	**7,70**	**2,26**	**0,44**	**37,92**	**0,960**	**62,68**	**5,8**	**5,8**	**6938,8**
21,50	**7,34**	**2,12**	**0,41**	**39,19**	**1,019**	**67,52 !**	**6,8**	**6,8**	**6918,9**
22,00	**7,01**	**1,98**	**0,39**	**40,49**	**1,082**	**72,72 !!**	**7,9**	**7,9**	**6898,5**

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Propulsion

17 may 2018 09:12
HydroComp NavCad 2014

Project ID	**LNG**
Description	**membrana**
File name	**navcad.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:	**275,710 m**	LCG fwd TR:[XCG/LP 0,000]	**0,000 m**
Max beam on WL:[LWL/BWL 6,127]	**45,000 m**	VCG below WL:	**0,000 m**
Max molded draft:[BWL/T 3,552]	**12,670 m**	Aft station (fwd TR):	**0,000 m**
Displacement:[CB 0,737]	**118826,00 t**	Deadrise:	**0,00 deg**
Wetted surface:[CS 2,665]	**15059,1 m2**	Chine beam:	**0,000 m**
ITTC-78 (CT)		Chine ht below WL:	**0,000 m**
LCB fwd TR:[XCB/LWL 0,512]	**141,190 m**	Fwd station (fwd TR):	**0,000 m**
LCF fwd TR:[XCF/LWL 0,490]	**134,970 m**	Deadrise:	**0,00 deg**
Max section area:[CX 0,964]	**549,7 m2**	Chine beam:	**0,000 m**
Waterplane area:[CWP 0,782]	**9704,2 m2**	Chine ht below WL:	**0,000 m**
Bulb section area:	**43,3 m2**	Propulsor type:	**Propeller**
Bulb ctr below WL:	**5,400 m**	Max prop diameter:	**9000,0 mm**
Bulb nose fwd TR:	**292,000 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:	**35,00 deg**	Device count:	**0**
Bow shape factor:[WL 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:		**1**		Oblique angle corr:	**Off**
Propulsor type:		**Propeller**		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:	**Custom**
Reference prop:				Scale correction:	**None**
Blade count:		**6**		KT multiplier:	**1,000**
Expanded area ratio:		**0,8423**	**[Size]**	KQ multiplier:	**1,000**
Propeller diameter:		**9000,0 mm**	**[Size]**	Blade T/C [0.7R]:	**0,00**
Propeller mean pitch:	[P/D 0,9946]	**8951,2 mm**	**[Size]**	Roughness:	**0,00 mm**
Hub immersion:		**6900,0 mm**		Cav breakdown:	**On**
Engine/gear				**Design condition**	
Engine data:		**Untitled**		Max prop diam:	**9000,0 mm**
Rated RPM:		**1400 RPM**		Design speed:	**19,50 kt**
Rated power:		**40000,0 kW**		Reference power:	**40000,0 kW**
Gear efficiency:		**0,970**		Design point:	**0,850**
Load correction:		**Off**		Reference RPM:	**600,0**
Gear ratio:		**8,330**	**[Size]**	Design point:	**1,030**
Shaft efficiency:		**0,970**			

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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

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