CUADERNO 6
PREDICCION DE POTENCIA Y DISEÑO DE PROPULSORES Y TIMONES

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GRADO EN INGENIERÍA DE PROPULSIÓN Y SERVICIOS DEL BUQUE

CURSO 2.012-2013

PROYECTO NÚMERO 13-P7

TIPO DE BUQUE : L.N.G.C. 170.000 m^3

CLASIFICACIÓN , COTA Y REGLAMENTOS DE APLICACIÓN : Bureau Veritas, Solas, Marpol.

CARACTERÍSTICAS DE LA CARGA: L.N.G.

VELOCIDAD Y AUTONOMÍA : 21 nudos al 90 % de MCR con un 10% de margen de mar y autonomía de 12.000 millas a velocidad de servicio.

SISTEMAS Y EQUIPOS DE CARGA / DESCARGA : Sistema de contención de la carga de doble membrana, sistema de descarga con bombas.

PROPULSIÓN : Propulsión diesel eléctrica.

TRIPULACIÓN Y PASAJE : 26

OTROS EQUIPOS E INSTALACIONES : Hélice transversal en proa . Las habituales en este tipo de buques.

Ferrol, Febrero de 2.013

ALUMNO : D. Horacio Carlos Orejas González.

CONTENIDO:

1. INTRODUCCION

En este cuaderno se calculará la potencia necesaria para propulsar el buque, partiendo del cálculo de la resistencia al avance. Calculada la potencia propulsiva se calculará el sistema de gobierno y maniobra necesarios para la operación del buque proyectado.

Para la resistencia al avance se utilizará el método de Holtrop, añadido en las librerías del software de cálculos hidrodinámicos NavCad.

Para el sistema de gobierno y maniobra se establece un timón semisuspendido. Para el sistema de maniobra se necesitarían cálculos específicos de resistencia al avance para esa condición de navegación. Se aproximarán los valores según los datos obtenidos por buques de referencia.

2. CÁLCULO DE LOS APÉNDICES

En este apartado se calcularán mediante la formulación que aportan las sociedades de clasificación, o por estimación según valores de buques de referencia, los parámetros que definen los apéndices del buque.

2.1 CÁLCULO DEL TIMÓN

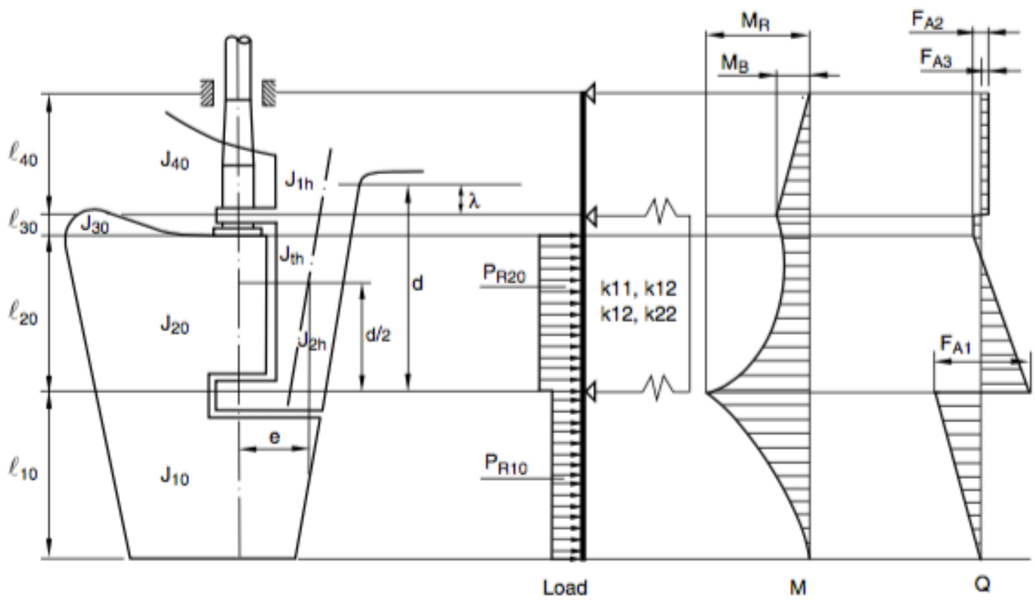
En este apartado se calcularán mediante la formulación que aportan las sociedades de clasificación, o por estimación según valores de buques de referencia, los parámetros que definen los apéndices del buque.

El tipo de timón será un timón semisuspendido con tres puntos de apoyo y un perfil NACA. Bureau Veritas clasifica este timón como un timón tipo 9. Este timón es bueno por razones de robustez, seguridad frente averías y disminución de las vibraciones.

Se sabe que este tipo de timón es bueno por razones de robustez, seguridad frente averías y disminución de las vibraciones, además, la mayoría de los buques de la base de datos lleva un timón de este tipo.

En la figura siguiente se muestra una configuración típica de este tipo de timones y el diagrama de cargas.

Figure 9 : Rudder type 9



CÁLCULO DEL ÁREA DEL TIMÓN

Según el libro el proyecto básico del buque mercante, el área del timón se determina con un porcentaje del área de deriva. Dicho porcentaje oscila, para buques de una hélice, entre 1,6-1,9%.

$$A_{timón} = 0{,}019 \cdot L_{pp} \cdot T = 0{,}019 \cdot 278 \cdot 11{,}6 = 61{,}27 m^2$$

DETERMINACIÓN DE LA CUERDA

La altura del timón será 11 m. Como el timón tiene forma rectangular, el cálculo de la longitud vendrá dado por la expresión siguiente:

$$Longitudpala = \frac{A_{timón}}{H_{timón}} = \frac{61{,}27}{11} = 5{,}57 m$$

2.2 DETERMINACIÓN DEL PAR DEL TIMÓN

El cálculo de fuerzas y momentos actuantes se realiza conforme al BV, Parte B, capítulo 10,Sección 1. Se muestra el extracto a continuación:

mulae 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} : Minimum yield stress, in N/mm², of the specified steel, 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} ≤ 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 (refer to [4.2.1]).

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

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

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

r_2 : Coefficient to be obtained from Tab 2

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 1 : Navigation coefficient

Navigation notation	Navigation coefficient n_R
Unrestricted navigation	1,00
Summer zone	0,95
Tropical zone	0,85
Coastal area	0,85
Sheltered area	0,75

Table 2 : Values of coefficient r_2

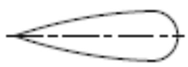
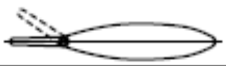
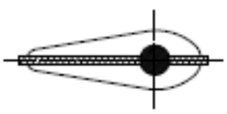
Rudder profile type	r_2 for ahead condition	r_2 for astern condition
NACA 00 - Goettingen 	1,10	0,80
Hollow 	1,35	0,90
Flat side 	1,10	0,90
High lift 	1,70	1,30
Fish tail 	1,40	0,80
Single plate 	1,00	1,00

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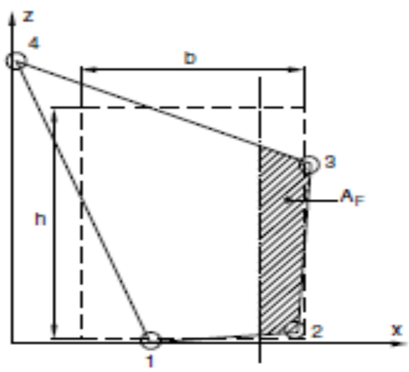
Figure 1 : Geometry of rudder blade without cut-outs



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 the 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:
  - $\alpha = 0{,}33$ for ahead condition
  - $\alpha = 0{,}66$ for astern condition
- A_F : Area, in m², 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.

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].

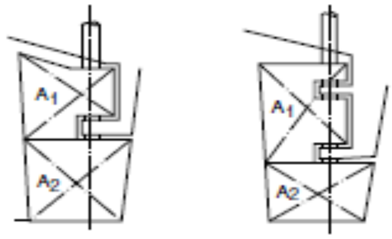
2.2.3 Rudder torque

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:

$$A = A_1 + A_2$$

Figure 2 : Rudder blades with cut-outs



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:

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

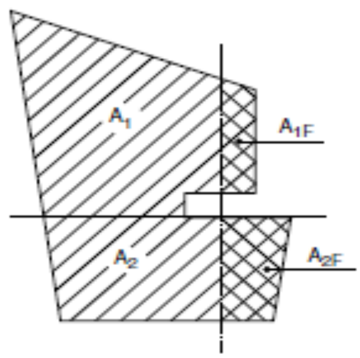
$$r_2 = b_2\left(\alpha - \frac{A_{2F}}{A_2}\right)$$

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 m², of the rudder blade parts, defined in Fig 3
- 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.

Figure 3 : Geometry of rudder blade with cut-outs



En los extractos del Bureau Veritas relacionados con el cálculo de las fuerzas actuantes sobre el timón se han recuadrado las expresiones que determinan los valores que éste debe satisfacer. A continuación se realizan dichos cálculos:

Cálculo de la fuerza del timón:

Marcha avante	
$C_R = 132 \cdot n_R \cdot A \cdot (V^2) \cdot r_1 \cdot r_2 \cdot r_3$	
n_R es el coeficiente de navegación.	1,0000
V es la velocidad del buque.	21,0000
$r_1 = (\lambda+2)/3$	1,2669
$\lambda = [(h^2)/A_1]<2$	1,8006
h = (z3 +z4 -z2)/2	11,0000
z3	11,0000
z4	11,0000
z2	0,0000
A_T = Area del timón.	67,2000
C_R =	6269,064 kN

Ciar	
$C_R = 132 \cdot n_R \cdot A \cdot (V^2) \cdot r_1 \cdot r_2 \cdot r_3$	
n_R es el coeficiente de navegación.	1,0000
V es la velocidad del buque.	10,5000
$r_1 = (\lambda+2)/3$	1,2669
$\lambda = [(h^2)/A_1]<2$	1,8006
h = (z3 +z4 -z2)/2	11,0000
z3	11,0000
z4	11,0000
z2	0,0000
A_T = Area del timón.	67,2000
C_R =	1139,830 kN

Cálculo del par del timón:

Marcha avante	
$M_{TR} = C_R \cdot r$	
C_R=	6269,0637
$r = b \cdot (\alpha - [A_F/A]) > 0,1$	0,2773
b = (x2+x3-x1)/2	6,2000
x1	0,0000
x2	7,2000
x3	5,2000
α	0,3300
A_F = Área a proa de la mecha =(	19,1700
A_T = Area del timón.	67,2000
M_{TR} =	1738,658 kN·m

Ciar	
$M_{TR} = C_R \cdot r$	
C_R=	1139,8298
$r = b \cdot (\alpha - [A_F/A]) > 0,1$	2,3233
b = (x2+x3-x1)/2	6,2000
x1	0,0000
x2	7,2000
x3	5,2000
α	0,6600
A_F = Área a proa de la mecha =(	19,1700
A_T = Area del timón.	67,2000
M_{TR} =	2648,211 kN·m

2.2 CÁLCULO DEL SERVOMOTOR

Para el cálculo de la potencia del servo se cogerá el mayor par torsor de los dos, en este caso es en la situación de ciar.

El SOLAS en su Capítulo II- 1.Parte C, Regla 29: Aparatos de gobierno nos dice lo siguiente:

La presión de proyecto utilizada en los cálculos para determinar los escantillones de las tuberías y de otros componentes del aparato de gobierno sometidos a presión hidráulica interna será por lo menos 1,25 veces la presión máxima de trabajo.

El aparato de gobierno principal y la mecha del timón:

Tendrán resistencia suficiente y permitirá el gobierno del buque a la velocidad máxima de servicio en marcha avante, lo cual deberá quedar demostrado;

Permitirán el cambio del timón desde una posición de 35º a una banda hasta otra de 35º a la banda opuesta hallándose el buque navegando a la velocidad máxima de servicio en marcha avante y con su calado máximo en agua salada, y, dadas las mismas condiciones, desde una posición de 35º a cualquiera de ambas bandas hasta otra de 30º a la banda opuesta, sin que ello lleve más de 28 s.

El aparato de gobierno auxiliar:

Tendrá resistencia suficiente para permitir el gobierno del buque a la velocidad normal de navegación y podrá entrar rápidamente en acción en caso de emergencia.

Permitirá el cambio del timón desde una posición de 15º a una banda hasta otra de 15º a la banda opuesta sin que ello lleve más de 60 s.

Entonces nosotros multiplicaremos el par mayor por un factor de riesgo igual a 1,3 y consideraremos que el rendimiento mecánico del sistema es η=0,8. Para calcular la potencia del servo en ambos casos, emplearemos la siguiente fórmula:

$$Potencia = \frac{T \cdot w}{\eta}$$

T es el par torsor máximo necesario en [kN·m].

w es la velocidad angular dl servo principal en [rad·s].

Cálculo del servomotor			
Potencia = (Tđw)/ɟ			
T =		2648.211	kNđm
w PPAL= (65º/28s)đ(2̂ rad/360º)		0.0405	rad/s
w EMRG =(30º/60s)đ(2̂ rad/360º)		0.0087	rad/s
ɟ =		0.8	
	Potencia servo ppal. =	174.357	kW
	Potencia servo emrg. =	37.554	kW

3. ESTIMACION DE LA POTENCIA PROPULSORA

Para esto recordaremos las dimensiones del buque que hemos obtenido en el cuaderno anterior.

Vol (m3)	Δ (t)	LPP (m)	B(m)	D(m)	T(m)	V(kn)	CB
1700000	113523,92	278	45,9	26,77	11,57	21	0,751

Para facilitar futuros cálculos se ha modelado el casco del buque en el software MaxSurf en la condición de carga referente al calado de diseño, obteniendo los siguientes datos.

	Measurement	Value	Units
1	Displacement	113663	t
2	Volume (displaced)	110890.537	m^3
3	Draft Amidships	11.570	m
4	Immersed depth	11.574	m
5	WL Length	278.337	m
6	Beam max extents o	45.888	m
7	Wetted Area	15489.717	m^2
8	Max sect. area	520.029	m^2
9	Waterpl. Area	10755.631	m^2
10	Prismatic coeff. (Cp)	0.766	
11	Block coeff. (Cb)	0.750	
12	Max Sect. area coeff	0.980	
13	Waterpl. area coeff.	0.842	
14	LCB length	145.154	from z
15	LCF length	140.259	from z
16	LCB %	52.151	from z
17	LCF %	50.392	from z
18	KB	6.095	m
19	KG fluid	0.000	m
20	BMt	14.872	m
21	BML	474.101	m
22	GMt corrected	20.967	m
23	GML	480.196	m
24	KMt	20.967	m
25	KML	480.196	m
26	Immersion (TPc)	110.245	tonne/c
27	MTc	1895.153	tonne.
28	RM at 1deg = GMt.Di	41591.208	tonne.
29	Length:Beam ratio	6.066	
30	Beam:Draft ratio	3.965	
31	Length:Vol^0.333 rati	5.793	
32	Precision	Medium	63 stati

El proceso teórico del cálculo de obtención de la potencia propulsora es el siguiente:

1. Cálculo de la resistencia al avance (Rt).
2. Cálculo de la potencia efectiva (EHP).

$$EHP = \frac{R_t \cdot v}{75}$$

donde:

Rt: Resistencia total al avance.

v: Velocidad del buque.

3. Potencia entregada a la hélice (DHP).

$$DHP = \frac{EHP}{\eta_D}$$

donde:

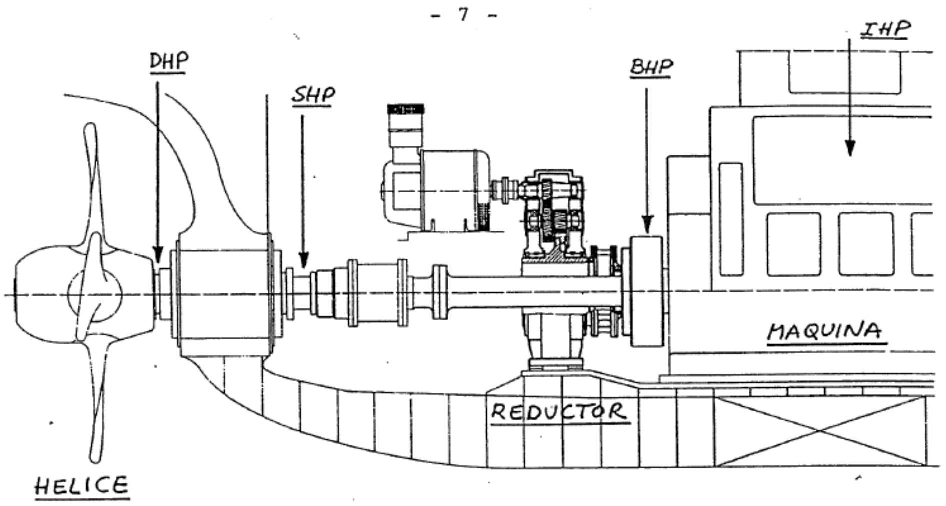
ηD: Rendimiento cuasi-propulsivo.

4. Potencia al freno (BHP)

$$BHP = DHP \cdot \eta_M$$

donde:

ηM: Rendimiento mecánico total de la línea de ejes. Incluyendo el reductor si da lugar.



Arrangement of engine room

La estimación de la potencia propulsora se realizará mediante el software NavCad. Se empezará introduciendo diferentes parámetros, unos obtenidos anteriormente y otros tomados directamente del buque base escalándolos sobre la Lpp para tomar medidas en verdadera magnitud.

Hull		
Configuration:	Monohull	
Chine type:	Round/multiple	
General		
Length on WL:	282,200	m
Max beam on WL:	45,900	m
Max molded draft:	11,570	m
Displacement:	113663,00	t
Wetted surface:	15402,5	m2
Demi-hull spacing:		m
ITTC-78 (CT)		
LCB fwd TR:	145,154	m
LCF fwd TR:	140,259	m
Max section area:	520,0	m2
Waterplane area:	10755,6	m2
Bulb section area:	9,6	m2
Bulb ctr below WL:	2,979	m
Bulb nose fwd TR:	291,000	m
Imm transom area:	0,0	m2
Transom beam WL:	0,000	m
Transom immersion:	0,000	m
Half entrance angle:	24,00	deg
Bow shape factor:	1,0	[WL flow]
Stern shape factor:	1,0	[WL flow]

Project		
Project ID:	LNG CAOREGON	
Description:		
Summary		
Scope:	ITTC-78 (CT)	
Configuration:	Monohull	
Chine type:	Round/multiple	
Length on WL:	282,200	m
Displacement:	113663,00	t
Propulsor type:	Propeller	
Count:	1	
Water properties		
Water type:	Salt	
Density:	1026,00	kg/m3
Viscosity:	1,18920e-6	m2/s
Speeds		
Speed [01]	14,00	kt
Speed [02]	15,00	kt
Speed [03]	16,00	kt
Speed [04]	17,00	kt
Speed [05]	18,00	kt
Speed [06]	19,00	kt
Speed [07]	20,00	kt
Speed [08]	21,00	kt
Speed [09]	22,00	kt
Speed [10]	23,00	kt
Design condition		
Design speed:	21,00	kt

Se añadirá un 10% de margen de mar como indica la RPA:

Margin		
Design margin:	10	%
Basis:	Hull + added dr...	

3.1 RESISTENCIA AL AVANCE (RT)

El programa Navcad permite hallar la resistencia al avance del buque mediante diferentes métodos predictivos. A su vez, califica los métodos posibles en: malos, buenos, muy buenos o excelentes en función de las características del buque. Para caso del buque de proyecto, el software ofrece como método excelente el método de Holtrop. Por lo tanto, se realizarán los cálculos utilizando este método.

Method Expert ranking

Method	Speed	Hull	Details
Holtrop	OK	OK	OK
Andersen	OK	OK	OK
Oortmerssen	OK	Uncertain	OK
Fung (CRTS)	OK	Uncertain	OK
Hamburg EWB Series	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
SSPA Cargo Series	OK	Uncertain	OK

Ranking: Best Good Fair Poor

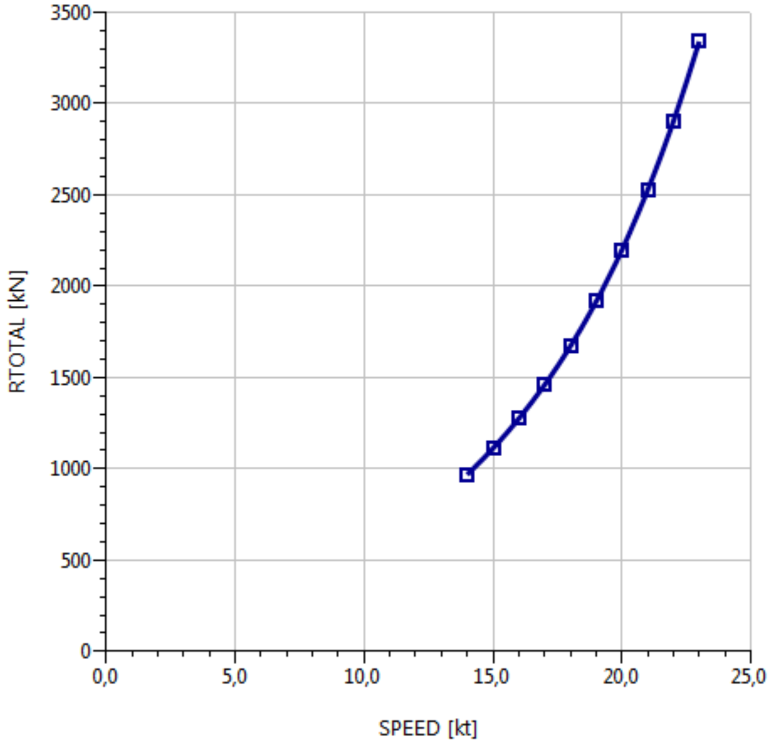
Parameters		
FN [design]	0,06··0,37	0,21
CP	0,55··0,85	0,75
LWL/BWL	3,90··14,90	6,15
BWL/T	2,10··4,00	3,97
Lambda	0,01··1,07	0,91

Con los datos de entrada anteriormente expuestos, el programa calcula la potencia efectiva total para el intervalo de velocidades comprendido entre 14 y 23 nudos.

Obteniendo unos resultados de:

RESISTANCE AND EFFECTIVE POWER									
RBARE [kN]	RAPP [kN]	RWIND [kN]	RSEAS [kN]	RCHAN [kN]	RTOWED [kN]	RMARGIN [kN]	RTOTAL [kN]	PEBARE [kW]	PETOTAL [kW]
968,73	0,00	0,00	0,00	0,00	0,00	0,00	968,73	6977,0	6977,0
1113,67	0,00	0,00	0,00	0,00	0,00	0,00	1113,67	8593,8	8593,8
1276,43	0,00	0,00	0,00	0,00	0,00	0,00	1276,43	10506,4	10506,4
1461,21	0,00	0,00	0,00	0,00	0,00	0,00	1461,21	12779,1	12779,1
1672,99	0,00	0,00	0,00	0,00	0,00	0,00	1672,99	15491,8	15491,8
1917,32	0,00	0,00	0,00	0,00	0,00	0,00	1917,32	18740,8	18740,8
2200,29	0,00	0,00	0,00	0,00	0,00	0,00	2200,29	22638,6	22638,6
2528,90	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**2528,90**	**27320,6**	**27320,6**
2906,10	0,00	0,00	0,00	0,00	0,00	0,00	2906,10	32890,5	32890,5
3341,32	0,00	0,00	0,00	0,00	0,00	0,00	3341,32	39535,3	39535,3

Speed (knots)	R_t (kN)
17	1461,21
18	1672,99
19	1917,32
20	2200,29
21	2528,90
22	2906,10
23	3341,32



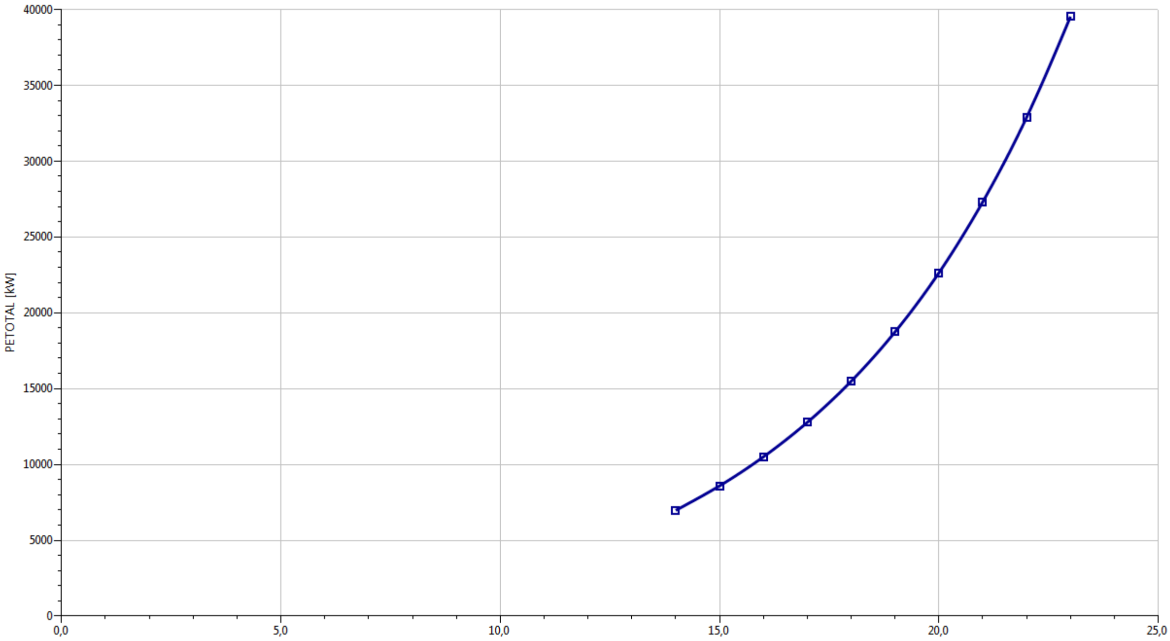
3.2 POTENCIA EFECTIVA (EHP)

La potencia efectiva (EHP) se define como:

$$EHP = \frac{R_t \cdot v}{75}$$

El valor de la potencia efectiva lo calcula el programa NavCad de forma automática.

RESISTANCE AND EFFECTIVE POWER									
RBARE [kN]	RAPP [kN]	RWIND [kN]	RSEAS [kN]	RCHAN [kN]	RTOWED [kN]	RMARGIN [kN]	RTOTAL [kN]	PEBARE [kW]	PETOTAL [kW]
968,73	0,00	0,00	0,00	0,00	0,00	0,00	968,73	6977,0	6977,0
1113,67	0,00	0,00	0,00	0,00	0,00	0,00	1113,67	8593,8	8593,8
1276,43	0,00	0,00	0,00	0,00	0,00	0,00	1276,43	10506,4	10506,4
1461,21	0,00	0,00	0,00	0,00	0,00	0,00	1461,21	12779,1	12779,1
1672,99	0,00	0,00	0,00	0,00	0,00	0,00	1672,99	15491,8	15491,8
1917,32	0,00	0,00	0,00	0,00	0,00	0,00	1917,32	18740,8	18740,8
2200,29	0,00	0,00	0,00	0,00	0,00	0,00	2200,29	22638,6	22638,6
2528,90	0,00	0,00	0,00	0,00	0,00	0,00	2528,90	27320,6	27320,6
2906,10	0,00	0,00	0,00	0,00	0,00	0,00	2906,10	32890,5	32890,5
3341,32	0,00	0,00	0,00	0,00	0,00	0,00	3341,32	39535,3	39535,3



3.3 POTENCIA ENTREGADA A LA HÉLICE (DHP)

La potencia entrega a la hélice (DHP) es la potencia que recibe directamente la hélice. No es medible ya que habría que instalar un torsiómetro en el exterior del buque, aunque puede estimarse.

$$DHP = \frac{EHP}{\eta_D}$$

El rendimiento cuasi-propulsivo (ηD) que sólo tiene en cuenta elementos hidrodinámicos se define como:

$$\eta D = \eta_H \cdot \eta_O \cdot \eta_R$$

Siendo:

η_D: Rendimiento cuasi-propulsivo.

η_H: Rendimiento del casco.

η_O: Rendimiento de la hélice.

η_R: Rendimiento rotativo relativo.

En un primer paso para obtener los valores de estos rendimientos, se realizan los cálculos mediante NavCad utilizando un propulsor basado en las referencias de un buque base.

SPEED COEFS			HULL-PROPULSOR				ENGINE		EFFICIENCY			
SPEED [kt]	FN	FV	PETOTAL [kW]	WFT	THD	EFFR	RPMENG [RPM]	PBPROP [kW]	EFFO	EFFG	EFFOA	MERIT
14,00	0,137	0,332	6977,0	0,4185	0,2085	1,0021	55	10020,5	0,5426	0,9700	0,7178	0,57374
15,00	0,147	0,356	8593,8	0,4177	0,2085	1,0021	59	12354,7	0,5427	0,9700	0,7171	0,57359
16,00	0,156	0,379	10506,4	0,4171	0,2085	1,0021	63	15141,9	0,5420	0,9700	0,7153	0,57427
17,00	0,166	0,403	12779,1	0,4164	0,2085	1,0021	67	18494,8	0,5403	0,9700	0,7123	0,57587
18,00	0,176	0,427	15491,8	0,4159	0,2085	1,0021	71	22557,6	0,5376	0,9700	0,7080	0,57843
19,00	0,186	0,450	18740,8	0,4153	0,2085	1,0021	76	27508,6	0,5338	0,9700	0,7023	0,58194
20,00	0,196	0,474	22638,6	0,4148	0,2085	1,0021	81	33563,8	0,5289	0,9700	0,6954	0,58635
21,00	**0,205**	**0,498**	**27320,6**	**0,4143**	**0,2085**	**1,0021**	**86**	**40992,2**	**0,5231**	**0,9700**	**0,6871**	**0,59157**
22,00	0,215	0,522	32890,5	0,4139	0,2085	1,0021	92	50013,8	0,5165	0,9700	0,6780	0,59728

w: coeficiente de estela → WFT (NavCad) = 0,4143

t: coeficiente de succión →THD (NavCad) = 0,2085

η_R : rendimiento relativo rotativo → EFFR (NavCad) = 1,0021

η_O : rendimiento de la hélice → EFFO (NavCad) = 0,5231

$$\eta_D = \eta_H \cdot \eta_O \cdot \eta_R = \frac{1-t}{1-w} \cdot \eta_O \cdot \eta_R = \frac{1-0{,}2085}{1-0{,}4143} \cdot 0{,}5231 \cdot 1{,}0021 = 0{,}7083$$

Por tanto:

$$DHP = \frac{EHP}{\eta_D} = \frac{27320,6}{0,7083} = 40177,36kW$$

3.4 POTENCIA AL FRENO (BHP)

La potencia al freno se define como:

$$BHP = DHP \cdot \eta_M$$

Siendo, ηM: Rendimiento mecánico. El rendimiento mecánico de la máquina incluye las pérdidas por rozamientos en los cilindros, cabeza y piezas de bielas y en los luchaderos del cigüeñal.

Una vez estimada la resistencia al avance se va a determinar la potencia necesaria (BHP). Se estudiará únicamente la condición de navegación en aguas libres por ser la que corresponde a nuestro tipo de buque.

Para ello vamos a usar nuevamente el NavCad. El método de predicción esta vez será el de Holtrop 1984.

Nuevamente se deberán introducir los datos de la carena. Además, se deberán añadir algunos datos referentes al propulsor, que en una primera aproximación será el del buque base.

- Opción Delivered thrust de programa.
- Se deberán indicar el número de propulsores, que será 1.
- La serie de la hélice: Serie B.
- El número de palas. Esto será orientativo, más adelante se determinará con precisión. En este caso se han supuesto 5.
- Diámetro de la hélice. En cuanto a los datos del propulsor se ha medido sobre el plano que se dispone del buque base un diámetro de 8,8 m
- Inmersión del eje. Otra vez se medirá sobre plano y se obtiene una inmersión de 6,9 m.
- El criterio de cavitación será el de Keller.

Hull-propulsor	Calc	
Technique:		Prediction
Prediction:		Holtrop
Reference ship:		
Max prop diam:	[mm]	9000,0
Corrections		
Viscous scale corr:	Off	
Rudder location:		
Friction line:		
Hull form factor:		
Corr allowance:		
Roughness [mm]:	Off	
Ducted prop corr:	Off	
Tunnel stern corr:	Off	
Effective diam:	[m]	
Recess depth:	[m]	
System analysis		
Cavitation criteria:		Keller eqn
Analysis type:		Free run
CPP method:		Fixed RPM
Engine RPM:		
Mass multiplier:		
RPM constraint:		
Limit [RPM/s]:		

	Type	Task
☐		Right-click to add a task...

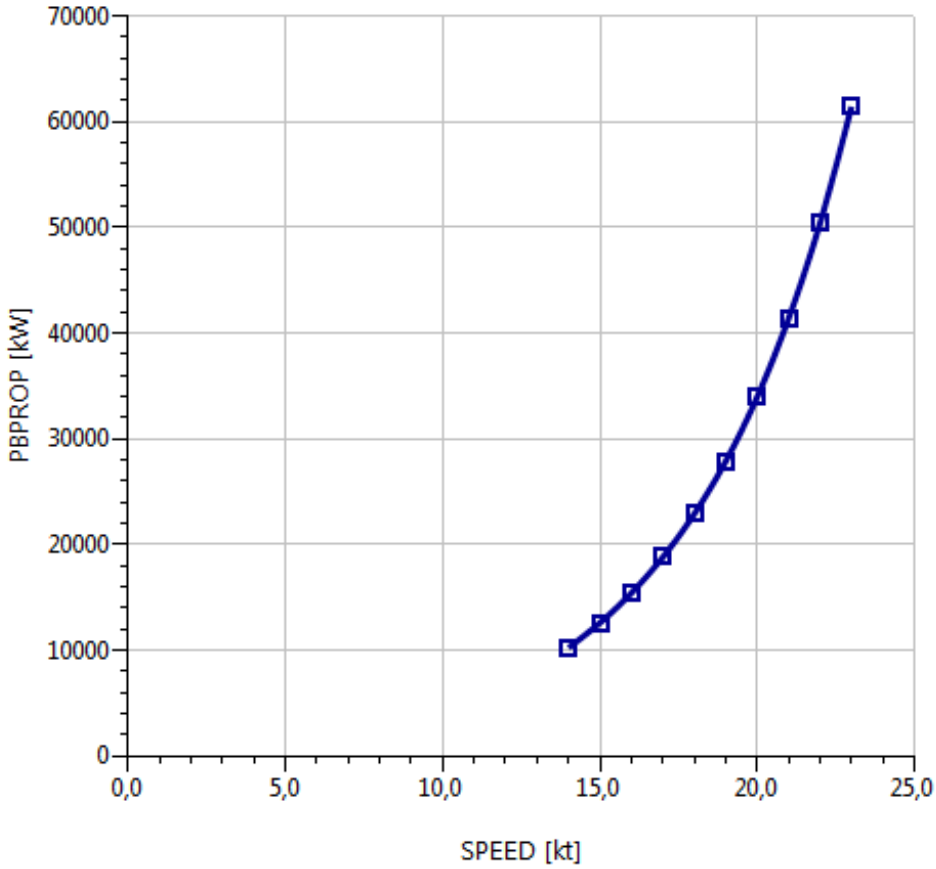
Propulsor		
Count:	1	
Propulsor type:	Propeller series	
Propeller type:	FPP	
Propeller series:	B Series	
Propeller sizing:	By thrust	
Reference prop:		
Blade count:	5	
Expanded area ratio:	0,7409	
Propeller diameter:	8800,0	mm
Propeller mean pitch:	8207,2	mm
Hub immersion:	6900,0	mm
Engine/gear		
Engine data:	None defined	
Rated RPM:		RPM
Rated power:		kW
Gear efficiency:	0,970	
Load correction:	Off	
Gear ratio:	0,000	
Shaft efficiency:	0,970	
Propeller options		
Oblique angle corr:	Off	
Shaft angle to WL:	0,00	deg
Added rise of run:	0,00	deg
Propeller cup:	0,0	mm
KTKQ corrections:	Custom	
Scale correction:	None	
KT multiplier:	1,000	
KQ multiplier:	1,000	
Blade T/C [0.7R]:	0,00	
Roughness:	0,00	mm
Cav breakdown:	Off	
Nozzle L/D:	0,50	

Propeller sizing

To size			
Gear ratio:	Keep	1,00	
Expanded area ratio:	Size	**0,741**	
Propeller diameter:	Keep	8800,0	mm
Propeller mean pitch:	Size	**6783,2**	mm
Design condition			
Design speed:		21,00	kt
Reference thrust:		2528,90	kN
Design point:		1,000	
Reference RPM:		88,9	
Design point:		1,030	
Max prop diam:		9000,0	mm
Review			
Tip speed:		42,19	m/s

Size | Save report | OK | Cancel | Help

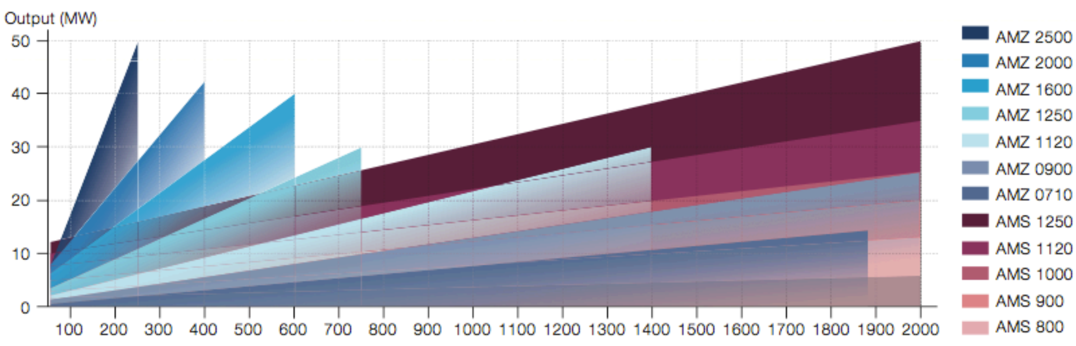
ENGINE				EFFICIENCY				THRUST		
RPMENG [RPM]	PBPROP [kW]	FUEL [L/h]	LOADENG [%]	EFFO	EFFG	EFFOA	MERIT	THRPROP [kN]	DELTHR [kN]	RPMPROP [RPM]
72	15405,1	---	30,8	0,5345	0,9669	0,7054	0,56629	1612,73	1276,42	72
77	18794,7	---	37,6	0,5330	0,9676	0,7027	0,5681	1846,20	1461,21	77
82	22893,4	---	45,8	0,5307	0,9682	0,6989	0,57101	2113,77	1672,98	82
87	27877,0	---	55,8	0,5274	0,9687	0,6940	0,575	2422,48	1917,32	87
93	33958,1	---	67,9	0,5232	0,9692	0,6878	0,58001	2780,01	2200,29	93
99	41400,3	---	82,8	0,5181	0,9696	0,6806	0,58595	3195,20	2528,90	99
105	50419,3	---	100,8	0,5124	0,9700	0,6725	0,59247	3671,77	2906,09	105
112	61424,2	---	122,8	0,5059	0,9700	0,6635	0,59958	4221,68	3341,32	112



Obteniendo así una potencia necesaria de 41400 kW.

BHP=41400/0,9 = 45546, 89 kW

Con este dato se escoge un motor eléctrico de velocidad variable de la casa ABB.



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

Este motor puede proporcionar hasta 50 MW a 250 rpm.

4. ELECCIÓN DE LOS PROPULSORES

La propulsión del buque proyectado es eléctrica por tanto son motores eléctricos los que generan el movimiento de la hélice. Los motores duales (diésel – gas) que el buque lleva instalados no son propulsores sino, generadores. Es decir, se encargan de generar la energía eléctrica suficiente para alimentar a los motores eléctricos y demás consumidores del buque.

Para el cálculo de la hélice lo primero que se buscará será las rpm óptimas a las que va a operar el propulsor para después conseguir el diámetro óptimo. Destacar que se buscará el punto de diseño de la hélice óptimo teniendo en cuenta que esta se puede cargar en un futuro por ensuciamiento del casco o del mismo equipo propulsor. Para ello primero se introducirán los datos del motor en el software y mantendremos el diámetro del propulsor del buque base.

En este punto, como se tiene el motor escogido se escoge la pestaña de propeller sizing by power para el diseño del propulsor.

Propeller sizing

To size			
Gear ratio:	Size	**2,885**	
Expanded area ratio:	Size	**0,976**	
Propeller diameter:	Keep	8800,0	mm
Propeller mean pitch:	Size	**8317,7**	mm
Design condition			
Design speed:		21,00	kt
Reference power:		50000,0	kW
Design point:		1,000	
Reference RPM:		250,0	
Design point:		1,030	
Max prop diam:		9000,0	mm
Review			
Tip speed:		41,13	m/s

Size | Save report | OK | Cancel | Help

HULL-PROPULSOR				ENGINE				EFFICIENCY			
PETOTAL [kW]	WFT	THD	EFFR	RPMENG [RPM]	PBPROP [kW]	FUEL [L/h]	LOADENG [%]	EFFO	EFFG	EFFOA	MERIT
10506,4	0,4171	0,2085	0,9880	179	15803,1	---	31,6	0,5300	0,9640	0,6897	0,56156
12779,1	0,4164	0,2085	0,9880	191	19274,6	---	38,5	0,5284	0,9653	0,6868	0,56316
15491,8	0,4159	0,2085	0,9880	204	23477,7	---	47,0	0,5258	0,9665	0,6827	0,56571
18740,8	0,4153	0,2085	0,9880	217	28595,9	---	57,2	0,5221	0,9675	0,6773	0,56922
22638,6	0,4148	0,2085	0,9880	232	34850,7	---	69,7	0,5175	0,9685	0,6707	0,57362
27320,6	**0,4143**	**0,2085**	**0,9880**	**247**	**42518,5**	**---**	**85,0**	**0,5118**	**0,9694**	**0,6629**	**0,57883**
32890,5	0,4139	0,2085	0,9880	262	51831,6	---	103,7	0,5055	0,9700	0,6542	0,58454
39535,3	0,4134	0,2085	0,9880	279	63229,1	---	126,5	0,4985	0,9700	0,6446	0,59075

POWER DELIVERY						
RPMPROP [RPM]	QPROP [kN·m]	QENG [kN·m]	PDPROP [kW]	PSPROP [kW]	PSTOTAL [kW]	PBTOTAL [kW]
62	2244,54	778,07	14776,9	15233,9	15233,9	15803,1
66	2567,53	890,03	18047,8	18606,0	18606,0	19274,6
71	2936,09	1017,79	22010,3	22691,1	22691,1	23477,7
75	3359,41	1164,53	26837,8	27667,8	27667,8	28595,9
80	3847,40	1333,69	32740,2	33752,8	33752,8	34850,7
86	**4411,59**	**1529,27**	**39979,1**	**41215,6**	**41215,6**	**42518,5**
91	5056,72	1752,90	48768,4	50276,7	50276,7	51831,6
97	5798,30	2009,97	59492,2	61332,2	61332,2	63229,1

De esta manera en una primera aproximación, se obtiene que las rpm del buque serán 86.

El siguiente paso será obtener el diámetro óptimo para estas rpm, se fijará un diámetro máximo de 9 m.

Obteniendo los siguientes resultados:

Propeller sizing

To size			
Gear ratio:	Keep	1,00	
Expanded area ratio:	Size	**0,952**	
Propeller diameter:	Size	**9000,0**	mm
Propeller mean pitch:	Size	**8208,0**	mm
Design condition			
Design speed:		21,00	kt
Reference power:		50000,0	kW
Design point:		1,000	
Reference RPM:		86,0	
Design point:		1,030	
Max prop diam:		9000,0	mm
Review			
Tip speed:		41,74	m/s

Size Save report OK Cancel Help

SPEED COEFS			HULL-PROPULSOR			
SPEED [kt]	FN	FV	PETOTAL [kW]	WFT	THD	EFFR
16,00	0,156	0,379	10506,4	0,4171	0,2085	0,9909
17,00	0,166	0,403	12779,1	0,4164	0,2085	0,9909
18,00	0,176	0,427	15491,8	0,4159	0,2085	0,9909
19,00	0,186	0,450	18740,8	0,4153	0,2085	0,9909
20,00	0,196	0,474	22638,6	0,4148	0,2085	0,9909
21,00	**0,205**	**0,498**	**27320,6**	**0,4143**	**0,2085**	**0,9909**
22,00	0,215	0,522	32890,5	0,4139	0,2085	0,9909
23,00	0,225	0,545	39535,3	0,4134	0,2085	0,9909

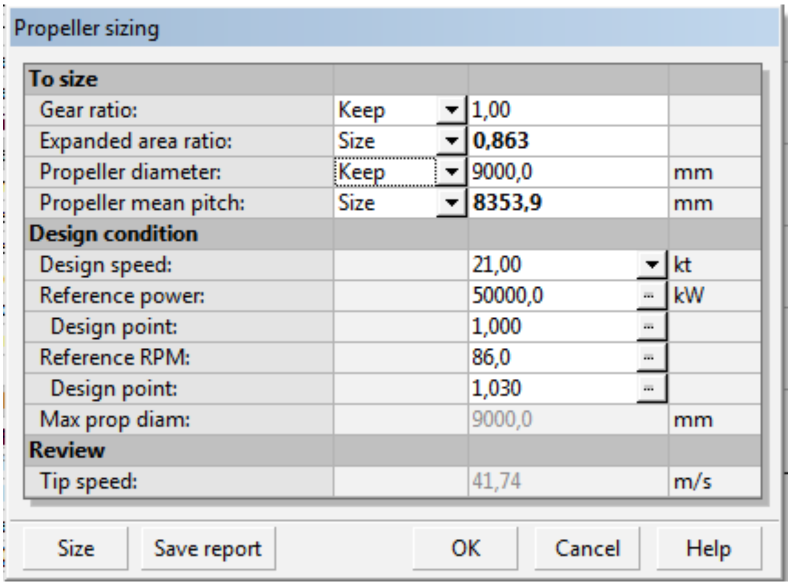
ENGINE				EFFICIENCY			
RPMENG [RPM]	PBPROP [kW]	FUEL [L/h]	LOADENG [%]	EFFO	EFFG	EFFOA	MERIT
61	15510,1	---	31,0	0,5367	0,9672	0,7004	0,55595
66	18928,3	---	37,9	0,5351	0,9678	0,6976	0,55761
70	23065,7	---	46,1	0,5325	0,9684	0,6936	0,56026
75	28102,2	---	56,2	0,5290	0,9689	0,6883	0,5639
79	34254,8	---	68,5	0,5245	0,9693	0,6818	0,56847
84	**41794,0**	**---**	**83,6**	**0,5190**	**0,9697**	**0,6741**	**0,57388**
90	50940,7	---	101,9	0,5128	0,9700	0,6656	0,57981
96	62112,9	---	124,2	0,5059	0,9700	0,6562	0,58627

Resumiendo, se ha obtenido un diámetro óptimo de 9 m y una relación de reducción para la caja reductora de 1:2.9.

Para continuar, el siguiente paso será comprobar para que nº de palas el rendimiento es mayor, para ello se comprobará con 4,5 y 6 palas.

4.1 PROPULSOR DE 4 PALAS

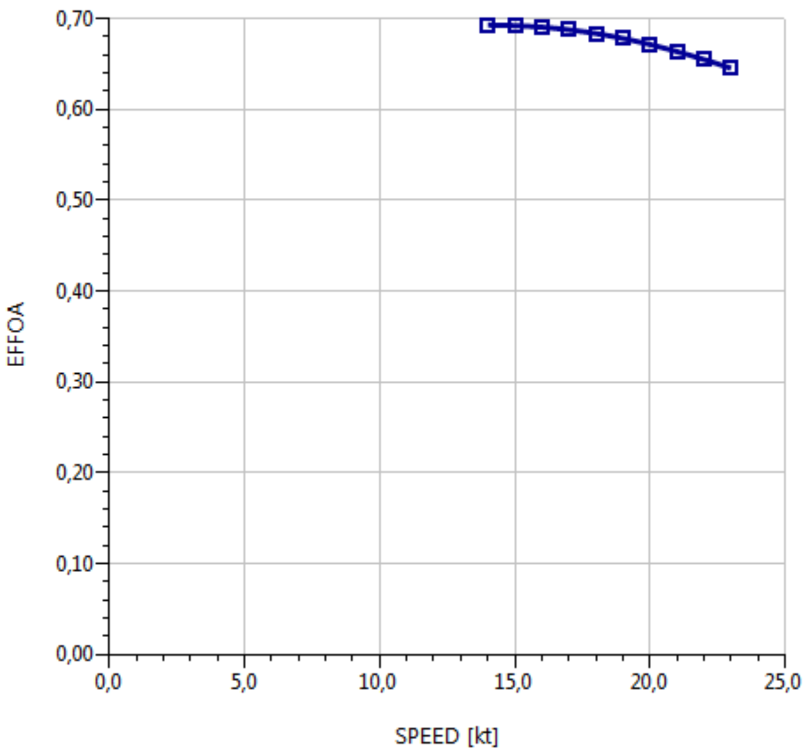
A continuación, se presentan los datos obtendidos con el software NavCad.



Propeller sizing

To size			
Gear ratio:	Keep	1,00	
Expanded area ratio:	Size	**0,863**	
Propeller diameter:	Keep	9000,0	mm
Propeller mean pitch:	Size	**8353,9**	mm
Design condition			
Design speed:		21,00	kt
Reference power:		50000,0	kW
Design point:		1,000	
Reference RPM:		86,0	
Design point:		1,030	
Max prop diam:		9000,0	mm
Review			
Tip speed:		41,74	m/s

Size | Save report | OK | Cancel | Help



SPEED COEFS			HULL-PROPULSOR			
SPEED [kt]	FN	FV	PETOTAL [kW]	WFT	THD	EFFR
16,00	0,156	0,379	10506,4	0,4171	0,2085	0,9896
17,00	0,166	0,403	12779,1	0,4164	0,2085	0,9896
18,00	0,176	0,427	15491,8	0,4159	0,2085	0,9896
19,00	0,186	0,450	18740,8	0,4153	0,2085	0,9896
20,00	0,196	0,474	22638,6	0,4148	0,2085	0,9896
21,00	0,205	0,498	27320,6	0,4143	0,2085	0,9896
22,00	0,215	0,522	32890,5	0,4139	0,2085	0,9896
23,00	0,225	0,545	39535,3	0,4134	0,2085	0,9896

ENGINE				EFFICIENCY			
RPMENG [RPM]	PBPROP [kW]	FUEL [L/h]	LOADENG [%]	EFFO	EFFG	EFFOA	MERIT
62	15732,1	---	31,5	0,5298	0,9672	0,6905	0,54883
66	19202,1	---	38,4	0,5282	0,9679	0,6876	0,55038
70	23405,0	---	46,8	0,5255	0,9684	0,6835	0,55287
75	28524,8	---	57,0	0,5218	0,9689	0,6781	0,55628
80	34783,6	---	69,6	0,5172	0,9693	0,6714	0,56057
85	42458,5	---	84,9	0,5115	0,9697	0,6636	0,56565
90	51778,5	---	103,6	0,5052	0,9700	0,6549	0,57122
96	63164,4	---	126,3	0,4982	0,9700	0,6453	0,57729

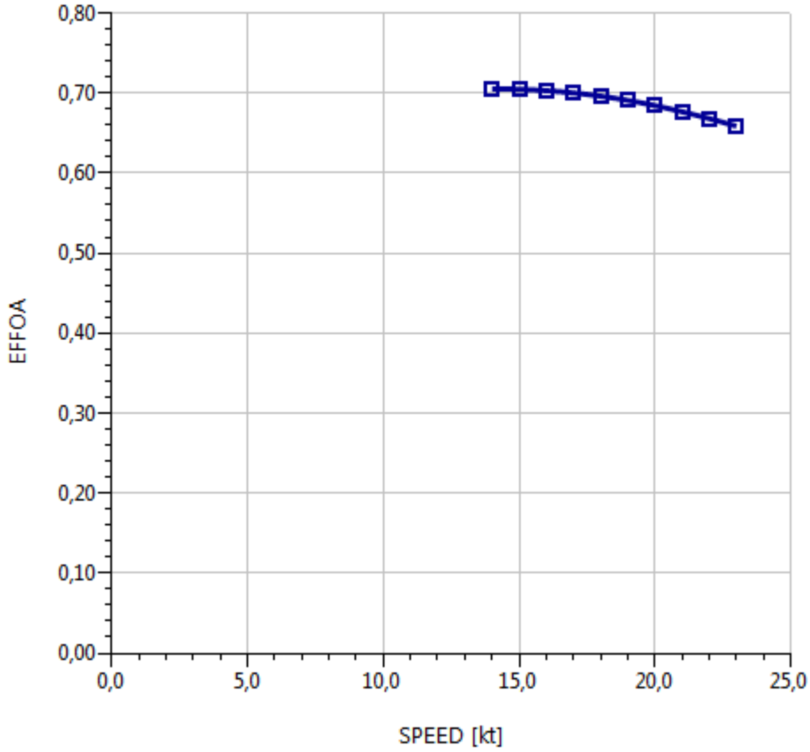
4.2 PROPULSOR DE 5 PALAS

A continuación se presentan los datos obtendidos con el software NavCad.

Propeller sizing

To size			
Gear ratio:	Keep	1,00	
Expanded area ratio:	Size	**0,954**	
Propeller diameter:	Keep	9000,0	mm
Propeller mean pitch:	Size	**8219,6**	mm
Design condition			
Design speed:		21,00	kt
Reference power:		50000,0	kW
Design point:		1,000	
Reference RPM:		86,0	
Design point:		1,030	
Max prop diam:		9000,0	mm
Review			
Tip speed:		41,74	m/s

Size | Save report | OK | Cancel | Help

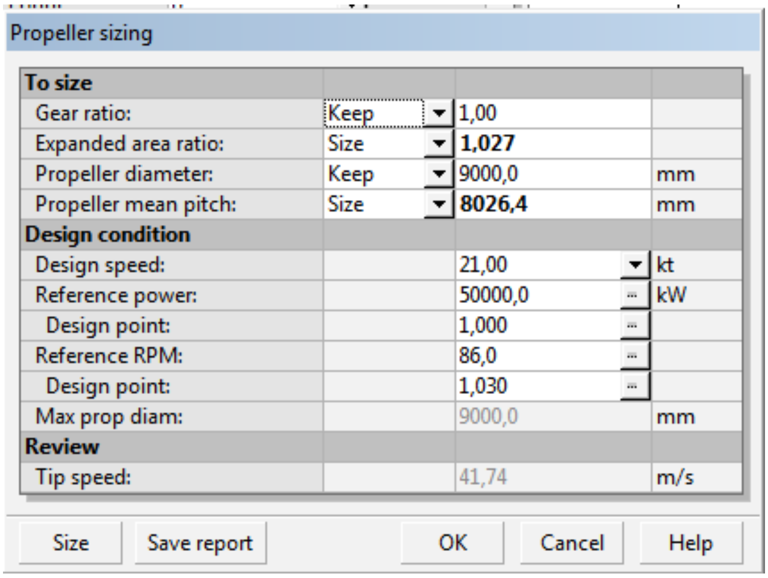


SPEED COEFS			HULL-PROPULSOR			
SPEED [kt]	FN	FV	PETOTAL [kW]	WFT	THD	EFFR
15,00	0,147	0,356	8593,8	0,4177	0,2085	0,9949
16,00	0,156	0,379	10506,4	0,4171	0,2085	0,9949
17,00	0,166	0,403	12779,1	0,4164	0,2085	0,9949
18,00	0,176	0,427	15491,8	0,4159	0,2085	0,9949
19,00	0,186	0,450	18740,8	0,4153	0,2085	0,9949
20,00	0,196	0,474	22638,6	0,4148	0,2085	0,9949
21,00	0,205	0,498	27320,6	0,4143	0,2085	0,9949
22,00	0,215	0,522	32890,5	0,4139	0,2085	0,9949

ENGINE				EFFICIENCY			
RPMENG [RPM]	PBPROP [kW]	FUEL [L/h]	LOADENG [%]	EFFO	EFFG	EFFOA	MERIT
57	12618,7	---	25,2	0,5372	0,9664	0,7047	0,55514
61	15452,0	---	30,9	0,5366	0,9672	0,7030	0,55584
66	18857,4	---	37,7	0,5350	0,9678	0,7002	0,5575
70	22979,2	---	46,0	0,5324	0,9684	0,6962	0,56015
74	27996,9	---	56,0	0,5289	0,9689	0,6909	0,56379
79	34126,6	---	68,3	0,5244	0,9693	0,6844	0,56835
84	41637,8	---	83,3	0,5189	0,9697	0,6767	0,57376
90	50750,5	---	101,5	0,5127	0,9700	0,6681	0,57968

4.3 PROPULSOR DE 6 PALAS

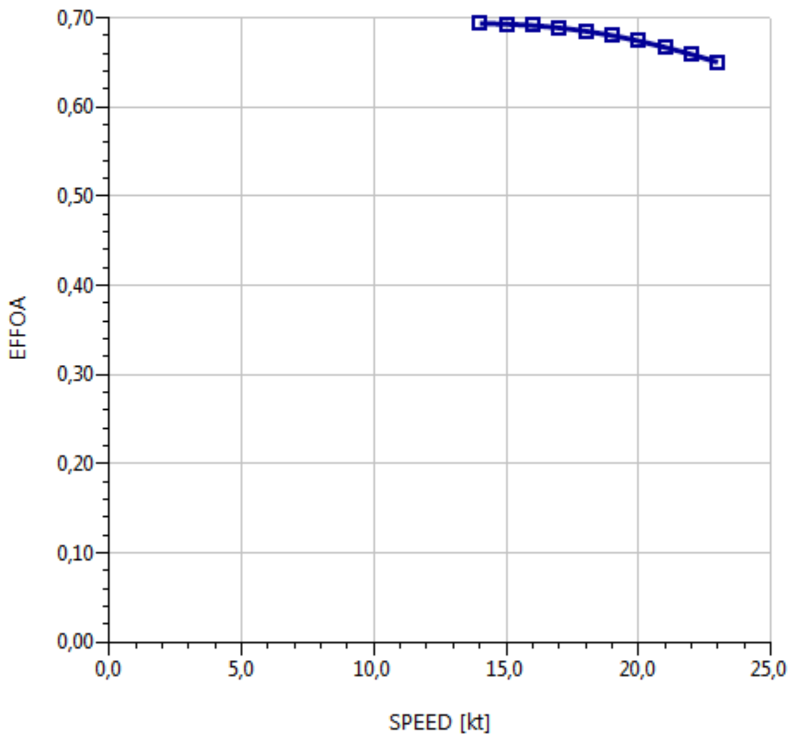
A continuación se presentan los datos obtendidos con el software NavCad



Propeller sizing

To size			
Gear ratio:	Keep	1,00	
Expanded area ratio:	Size	**1,027**	
Propeller diameter:	Keep	9000,0	mm
Propeller mean pitch:	Size	**8026,4**	mm
Design condition			
Design speed:		21,00	kt
Reference power:		50000,0	kW
Design point:		1,000	
Reference RPM:		86,0	
Design point:		1,030	
Max prop diam:		9000,0	mm
Review			
Tip speed:		41,74	m/s

Size | Save report | OK | Cancel | Help



SPEED COEFS			HULL-PROPULSOR			
SPEED [kt]	FN	FV	PETOTAL [kW]	WFT	THD	EFFR
16,00	0,156	0,379	10506,4	0,4171	0,2085	0,9895
17,00	0,166	0,403	12779,1	0,4164	0,2085	0,9895
18,00	0,176	0,427	15491,8	0,4159	0,2085	0,9895
19,00	0,186	0,450	18740,8	0,4153	0,2085	0,9895
20,00	0,196	0,474	22638,6	0,4148	0,2085	0,9895
21,00	**0,205**	**0,498**	**27320,6**	**0,4143**	**0,2085**	**0,9895**
22,00	0,215	0,522	32890,5	0,4139	0,2085	0,9895
23,00	0,225	0,545	39535,3	0,4134	0,2085	0,9895

ENGINE				EFFICIENCY			
RPMENG [RPM]	PBPROP [kW]	FUEL [L/h]	LOADENG [%]	EFFO	EFFG	EFFOA	MERIT
62	15712,4	---	31,4	0,5305	0,9672	0,6913	0,54958
66	19171,4	---	38,3	0,5291	0,9679	0,6887	0,55134
70	23354,2	---	46,7	0,5267	0,9684	0,6850	0,55414
75	28441,0	---	56,9	0,5235	0,9689	0,6801	0,558
80	34649,0	---	69,3	0,5193	0,9693	0,6740	0,56283
85	**42248,1**	**---**	**84,5**	**0,5142**	**0,9697**	**0,6669**	**0,56855**
90	51459,5	---	102,9	0,5084	0,9700	0,6589	0,57481
96	62701,8	---	125,4	0,5019	0,9700	0,6500	0,58163

4.4 CONCLUSIONES

Los rendimientos para los distintos números de palas han sido:

Nº de palas	Rendimiento	BHP (kW)
4	0,6636	42458,5
5	0,6767	41637,7
6	0,6669	42248,1

En vista de los resultados de la tabla, el rendimiento total del propulsor (EFFOA, cociente entre la potencia efectiva y la potencia en el eje) es mayor en una hélice de cinco palas.

En definitiva, la hélice seleccionada presenta una serie de características definidas a continuación, que han sido generadas por el NavCad.

Propulsor				**Propeller options**	
Count:		1		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:	**Custom**
Reference prop:				Scale correction:	**None**
Blade count:		**5**		KT multiplier:	**1,000**
Expanded area ratio:		**0,9544**	**[Size]**	KQ multiplier:	**1,000**
Propeller diameter:		**9000,0 mm**	**[Keep]**	Blade T/C [0.7R]:	**0,00**
Propeller mean pitch:	[P/D 0,9133]	**8220,0 mm**	**[Size]**	Roughness:	**0,00 mm**
Hub immersion:		**6900,0 mm**		Cav breakdown:	**Off**
Engine/gear				**Design condition**	
Engine data:		**Untitled Engine Obje...**		Max prop diam:	**9000,0 mm**
Rated RPM:		**250 RPM**		Design speed:	**21,00 kt**
Rated power:		**50000,0 kW**		Reference power:	**50000,0 kW**
Gear efficiency:		**0,970**		Design point:	**1,000**
Load correction:		**On**		Reference RPM:	**86,0**
Gear ratio:		**1,000**	**[Keep]**	Design point:	**1,030**
Shaft efficiency:		**0,970**			

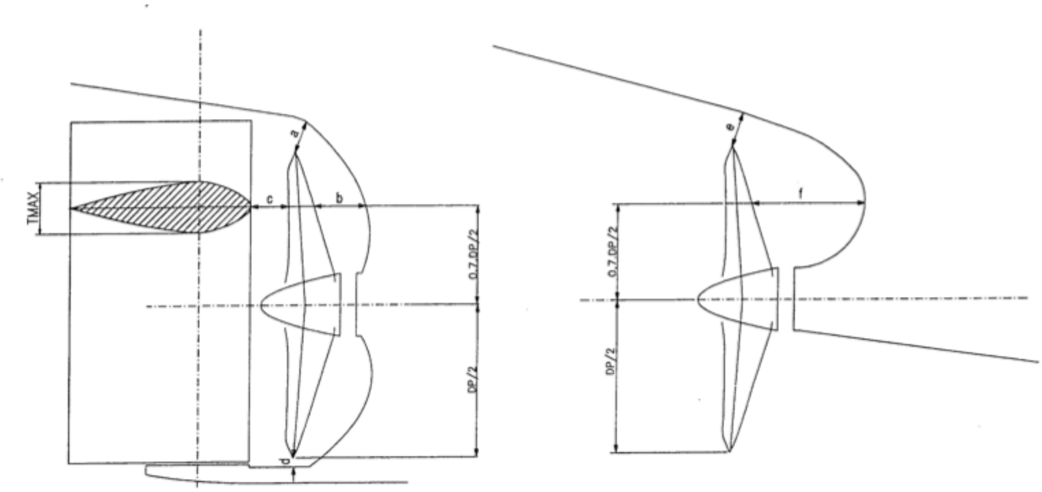
Con el propulsor adecuado, se volverá a calcular las BHP:

$$BHP = \frac{41637{,}7}{0{,}9} = 46007kW$$

El motor propulsor anteriormente escogido sigue siendo válido.

5. CLARAS EN EL CODASTE

Estos cálculos están basados en un reglamento distinto al de las especificaciones de las RPA, debido a que este último no trae información sobre estas medidas. Por ello se empleará el DNV (Det Norske Veritas) cuyas fórmulas aparecen en el proyecto báscio del buque mercante.



$a = (0{,}24 - 0{,}01 \cdot z)xDP$

a = 1,71 m

$b = (0{,}35 - 0{,}02 \cdot z)xDP$

b= 2,25 m

$c = 0{,}1 \cdot DP$

c = 0.9 m

$d = 0{,}035 \cdot DP$

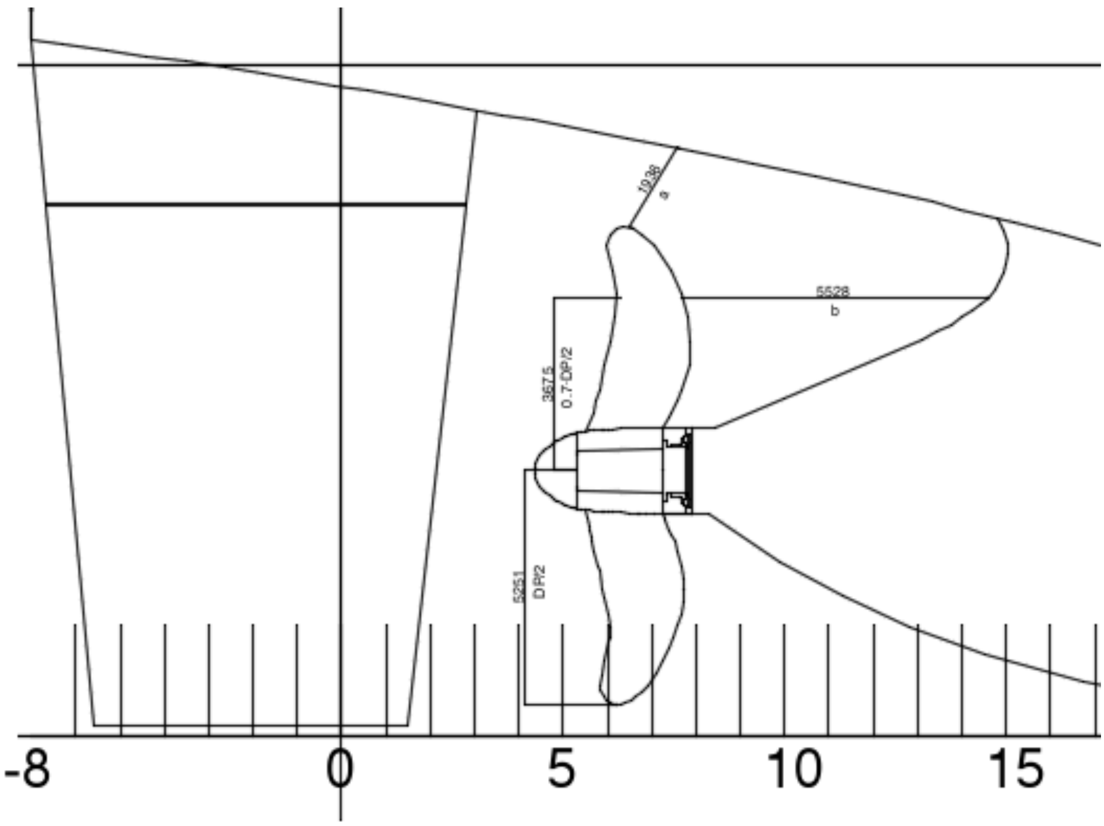
d=0,315 m

Donde:

Z: número de palas (5)

DP: diámetro de la hélice (9)

A continuación se muestra un plano con los huelgos del timón, donde se comprueba que se cumplen las medidas mínimas exigidas por la Sociedad de Clasificación.



Al analizar los huelgos (o claras) mínimas exigidos por la Sociedad de Clasificación se observa que los huelgos mínimos exigidos disminuyen al aumentar el número de palas del propulsor. Esto se debe a que el aumento del número de palas provoca un menor nivel de fluctuaciones de par y empuje transmitidos al casco y línea de eje. Por ello se deduce que es oportuno instalar hélices con el mayor número de palas.

6 HELICE TRANSVERSAL EN PROA

Hasta ahora se ha considerado que la maniobra de gobierno era obtenida exclusivamente con timones convencionales, aunque las exigencias de la reglamentación IMO se refieren a maniobra en general y se permite utilizar todos los recursos permanentes del buque.

Se dispondrá un empujador transversal en proa que generará un empuje normal al plano diametral, aspirando agua de una banda y arrojándola en la contraria, para ello se dispone de una hélice dentro de un conducto prácticamente cilíndrico que atraviesa el casco. Su cálculo se basa en determinar el empuje lateral a realizar por m^{2}, que es función del tipo de buque y de su eslora, y multiplicarlo por el área de deriva LppxT.

A continuación se indican unas fórmulas y gráficos para el dimensionamiento preliminar de estos empujadores.

Tipo de buque	Kg/m2 de obra viva	Kg/m2 de obra muerta
Ferry y Pasaje	9 a 14	4 a 8
Carga, remolcador	6 a 9	4 a 8
Petrol., Granelero	5 a 7	3 a 6
Dragas	9 a 12	4 a 8

Se debe adoptar el mayor de los dos valores del empuje obtenidos de esta tabla.

La siguiente gráfica relaciona el empuje necesario F (en kN por m^2 de obra viva) de diversos tipos de buque, en función de su eslora en metros y de la velocidad de giro VPSI que se pretende alcanzar, en grados por segundo.

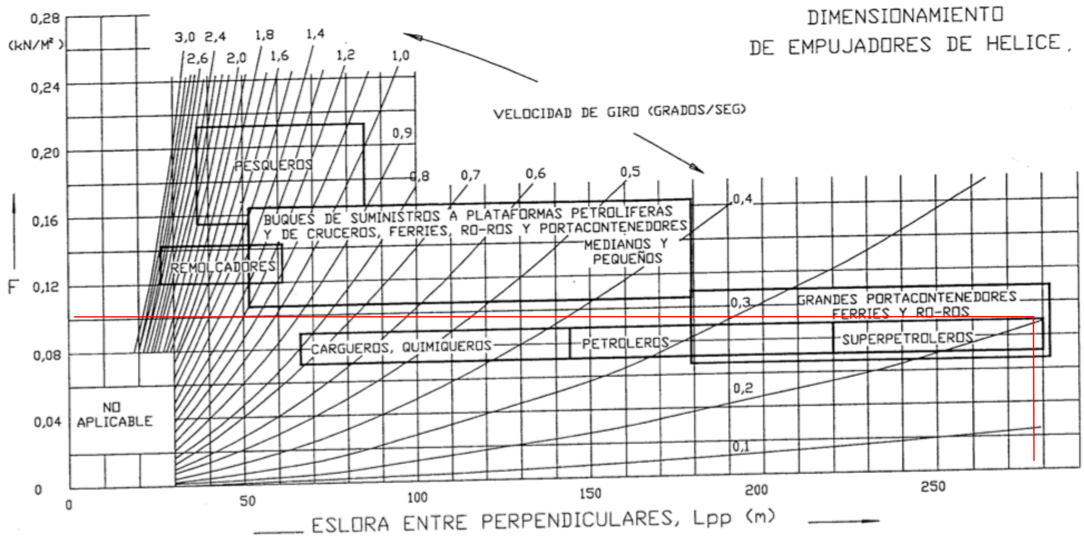


Figura 3.6.2.- Dimensionamiento de empujadores transversales.

VPSI=0,2 grad/s F=0,10 kN/m^2

7.1 POTENCIA NECESARIA

Los empujadores de hélice en un túnel transversal tienen un valor medio de 11 kg/HP, de la relación entre el empuje y la potencia del motor de accionamiento. Alternativamente la potencia del motor, se puede estimar por la siguiente fórmula, con un valor K deducido de la siguiente tabla.

$P = K \times DISW^{2/3}$

Tabla 3.6.3

Tipo de buque	K
Ferry	1.75
Carguero	0.90
Granelero	0.75
Draga	1.10

Entonces el empuje correspondiente es,

$Empuje_{hélicetransversal}$ = 0,10 x 278 x 11,57 = 321,65 kN (32808,3kg)

Con un valor normal de 11 kg por HP del motor accionador, resulta una potencia necesaria del motor de 2982,57 HP = 2193.38 Kw

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Antonio Baquero – E.T.S.I.N. (Madrid)

4) AYUDA SOFTWARE NAVCAD

CUADERNO 6
ANEXOS

Anexo 1

MOTOR PROPULSOR ABB AMZ 2500

Brochure

Synchronous motors
High performance in all applications

Power and productivity
for a better world™

We provide motors, generators and mechanical power transmission products, services and expertise to save energy and improve customers' processes over the total life cycle of our products, and beyond.

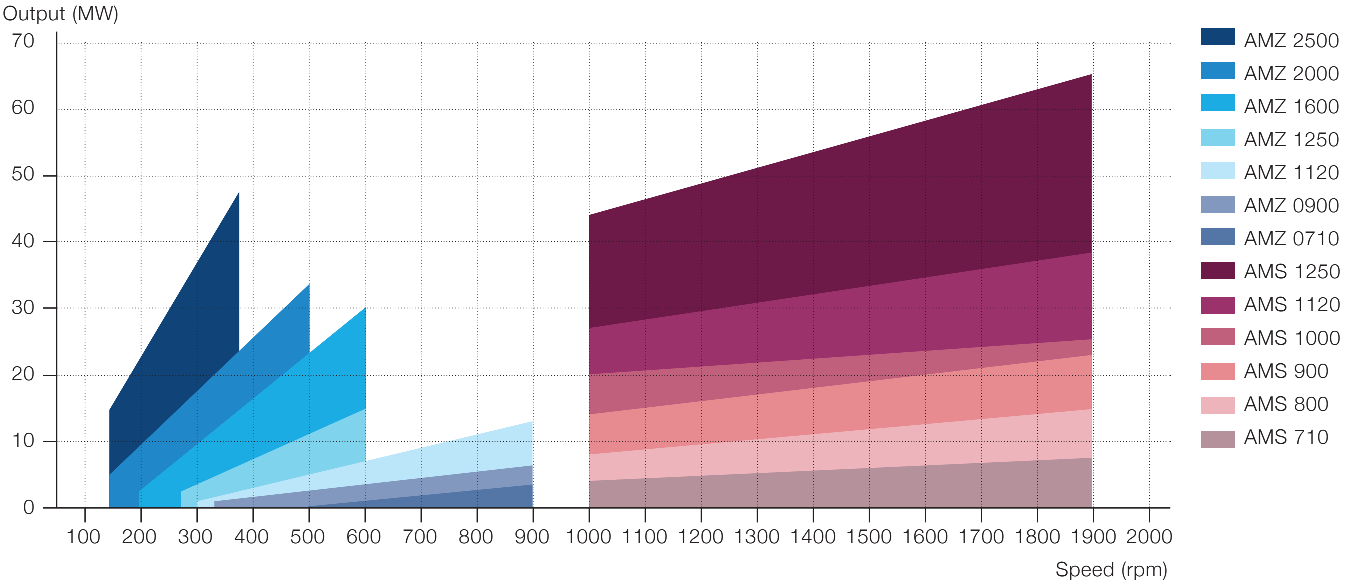
Synchronous motors from the world's leading supplier
Choose ABB efficiency and quality

ABB is the world's leading supplier of synchronous motors and generators. We have been designing and building AC motors for mission-critical applications for over a century, and our know-how and experience have made us the preferred supplier in many different industries.

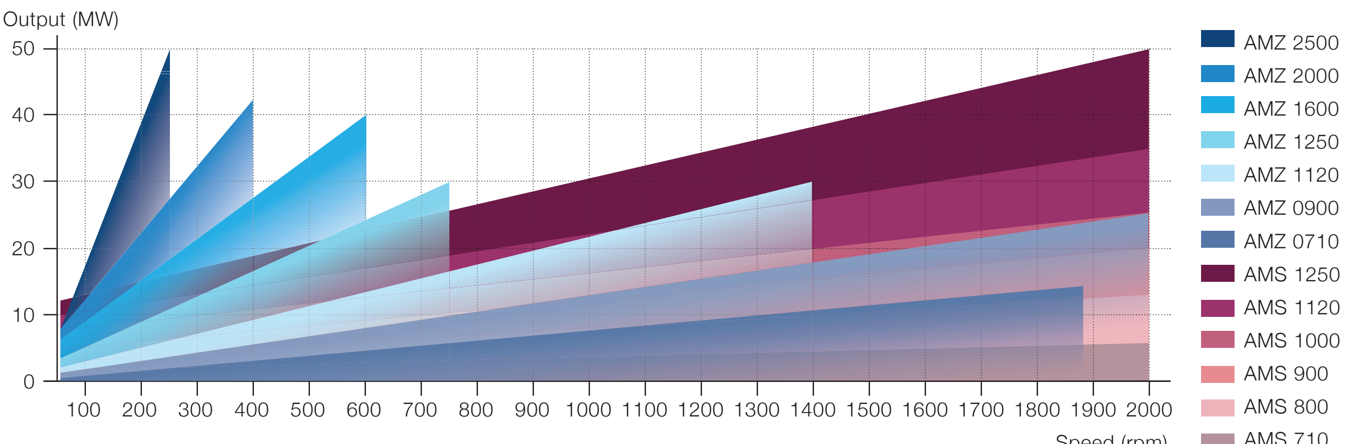
Our synchronous motors are delivering high performance in industrial processes, the marine and offshore sectors, utilities and specialized applications all over the world. In every case we work with our customers, using our expertise in different applications to tailor the optimum cost-effective solution based on our modular and standardized platforms.

Designed for outstanding levels of reliability and efficiency, our motors not only help our customers to cut operating, maintenance and energy costs, but also to reduce their environmental impact. Extensive service programs and our global organization ensure that we can support customers over their motors' entire life cycle.

Fixed speed motors



Variable speed motors



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

Fixed and variable speed motors tailored for each specific application

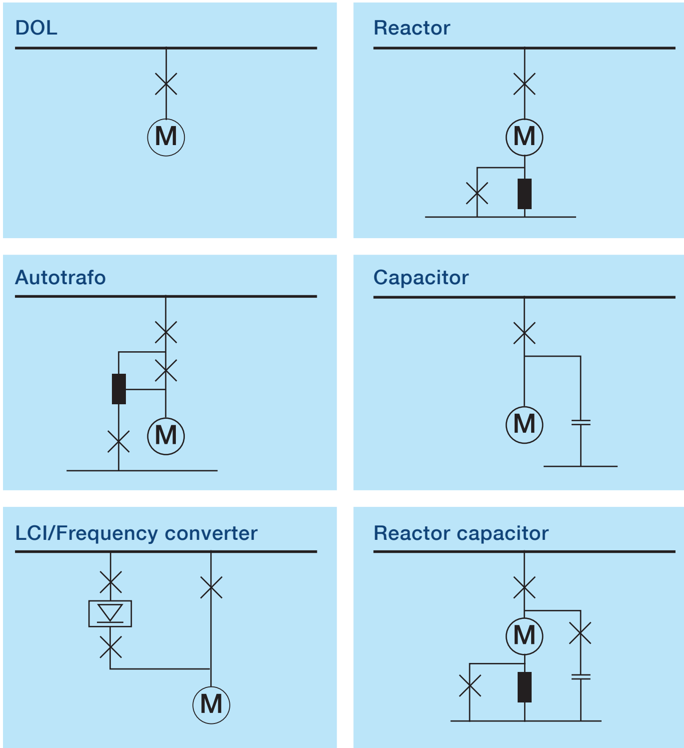
Fixed speed motors

Fixed speed synchronous motors are typically used in applications such as compressors, fans, pumps, wood grinders and refiners.

In each case we utilize advanced software tools to optimize the motor design for the specific application and ensure that the chosen starting method is appropriate. The results of this work are processed into an easy-to-understand format and incorporated into the technical specification we provide with each proposal.

We can engineer the motor to develop sufficient torque for smooth starting and acceleration with the starting current limited typically to 350 – 500% of the rated value. If this will result in unacceptable line voltage drops then we can investigate alternative starting methods.

The main factors to be considered in selecting the starting method are the customer's requirements, network capability and the demands of the process. The starting methods most commonly used for fixed speed synchronous motors are direct-on-line (DOL), reactor, autotransformer, Load Commutated Inverter (LCI or 'soft starter'), capacitor and reactor capacitor.



Typical starting methods for fixed speed synchronous motors.

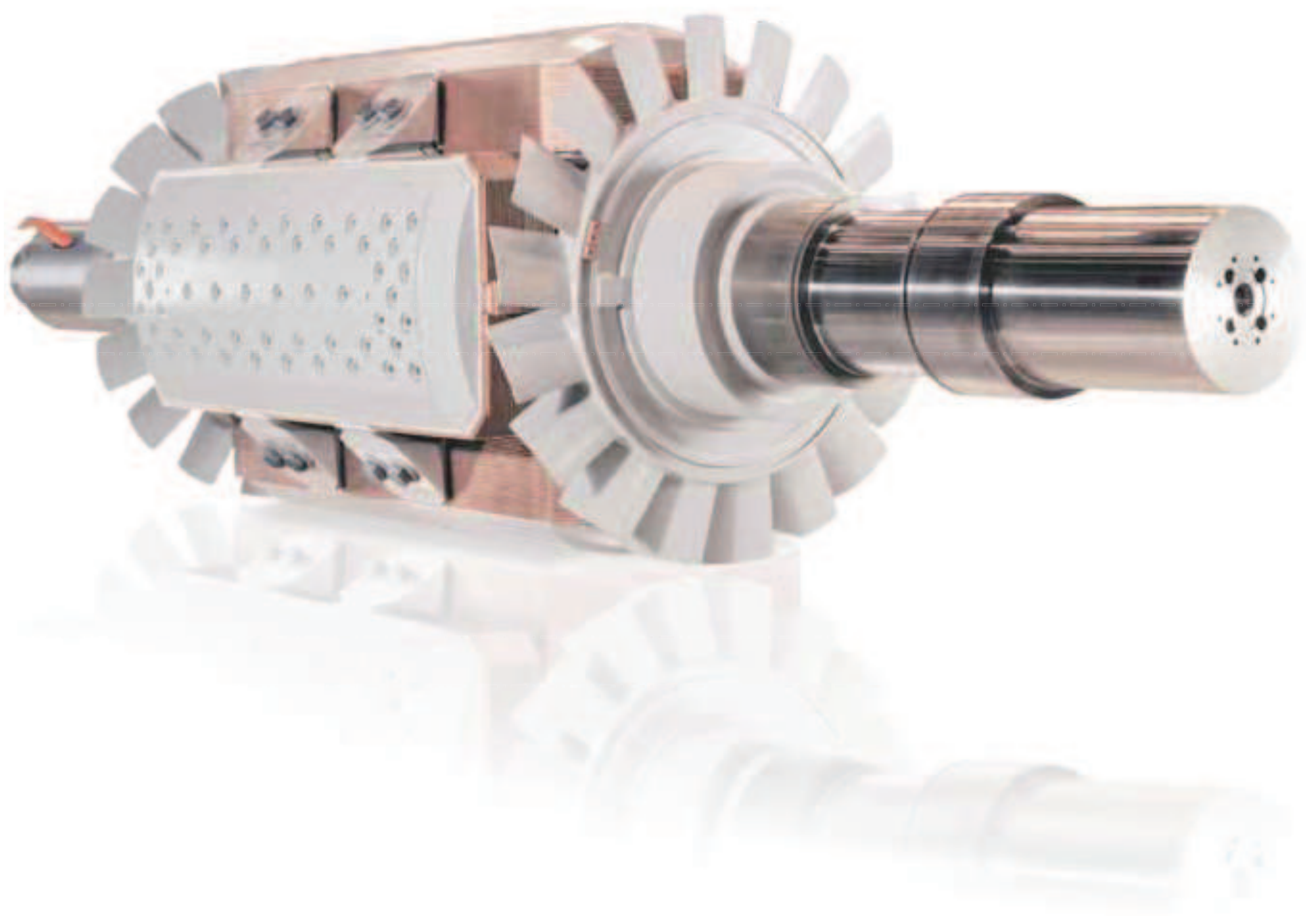
Variable speed motors

Variable speed synchronous motors are typically used in demanding applications in process industries, and applications where variable speed delivers clear benefits. Rolling mills, mine hoists, pumps, and compressors are examples of variable speed applications. Synchronous motors with variable speed drives (VSDs) are also commonly used in the main propulsion system in vessels. In applications such as extruders, compressors and pumps, optimized electrical drive systems based on variable speed motors can provide considerable energy savings.

We supply motors and drives that meet torque requirements over the entire operating range, from zero to maximum process speed. This ensures smooth starting, acceleration and operation. For the optimum variable speed solution, specify an ABB electrical drive package (ABB synchronous motor combined with an ABB drive such an ABB LCI or an ABB VSI like ACS 5000 or ACS 6000. When we supply electrical drive packages we apply our engineering and application know-how to ensure that all components, particularly the converter-motor interface, are optimally integrated to meet the needs of the process. Benefits include special converter-fed motor designs, increased efficiency and improved torque production capabilities.

In each case, we use specialized software tools to optimize the motor design with the converter type best suited for the application. All common converter types are supported: Load Commutated Inverter (LCI), Cycloconverter (C) and Voltage Source Inverter (VSI).

The rotor is key to excellent overall performance



The rotor plays a crucial part in achieving the best possible electrical and mechanical performance.

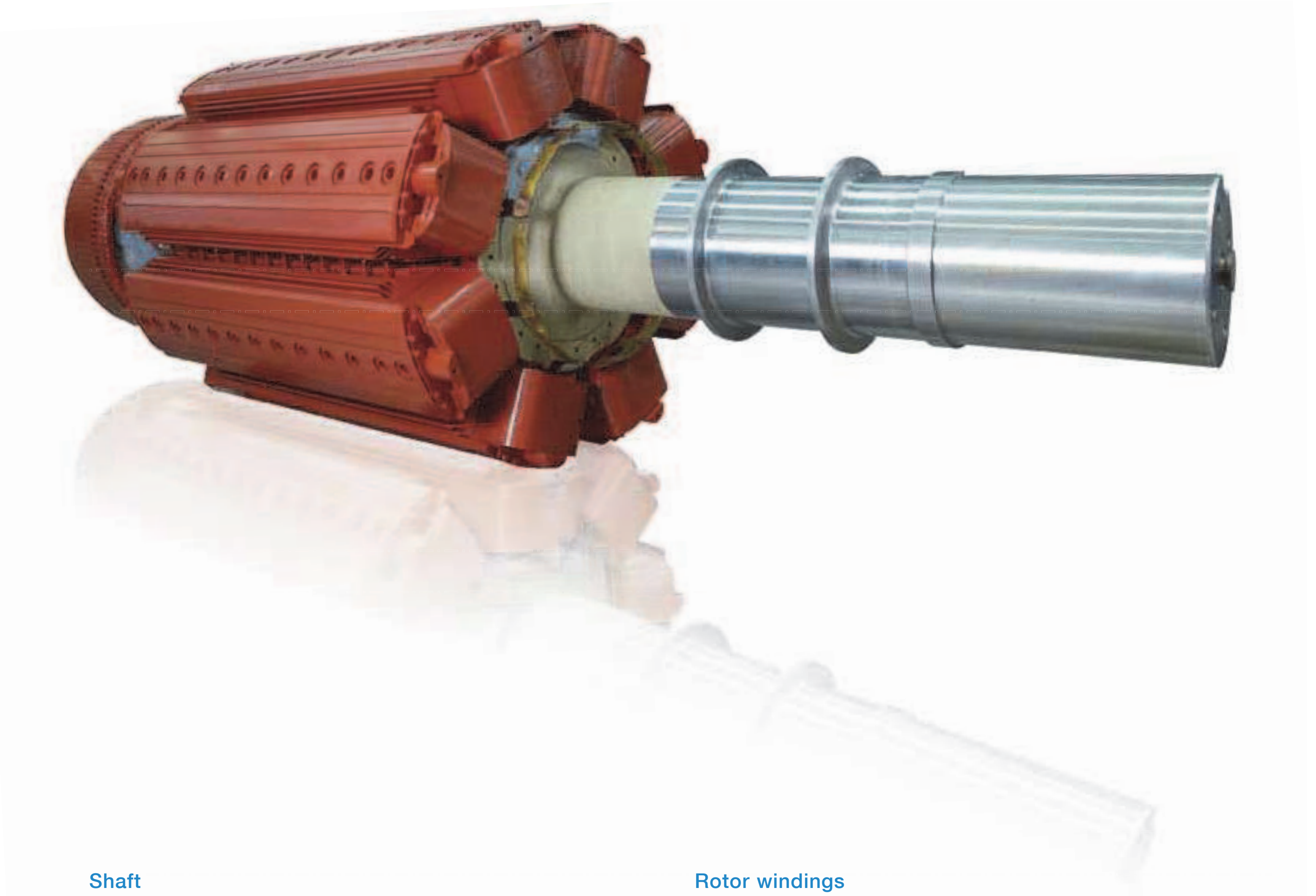
Higher speed motors

(four and six poles) have solid rotors with integrated poles made from a one-piece steel forging. A solid pole plate is attached to the pole, and this design has good overload capability and low harmonics. At the same time this rotor configuration contributes to the motors' excellent starting characteristics, high starting torque and low starting current. The large cooling surfaces and effective flow of cooling air mean that the rotor temperature remains low and uniform, helping to ensure reliability and a long operating life. The coils are class H insulated for extra thermal margins. The rigid rotor construction and minimum distance between bearings ensure that the motor operates below the first critical speed, keeping vibration levels low.

Lower speed motors

(eight or more poles) typically have rotors with the poles manufactured from 2 mm laminated steel sheet. The sheets are pressed together with inserted steel bars which are welded to the end plates. The poles are secured to the shaft or rotor center by bolts from above or below, or by means of dovetails. A copper or brass damper winding is often fitted. For lower speed motors the technically preferred option is to vacuum pressure impregnate (VPI) the rotor assembly after it is wound to achieve excellent insulation and mechanical strength. After impregnation, the complete rotor assembly is dynamically checked for balance.

Permanent magnet poles are used in certain variable speed applications. Permanent magnet rotors are straightforward constructions and do not need an excitation system. When necessary, high pole numbers can be used in low speed applications.



Shaft

The shaft is manufactured of forged or rolled steel and machined to exact specifications. The shaft ends can be cylindrical, conical or flanged, or two shaft ends can be provided (double end drive).

Rotor windings

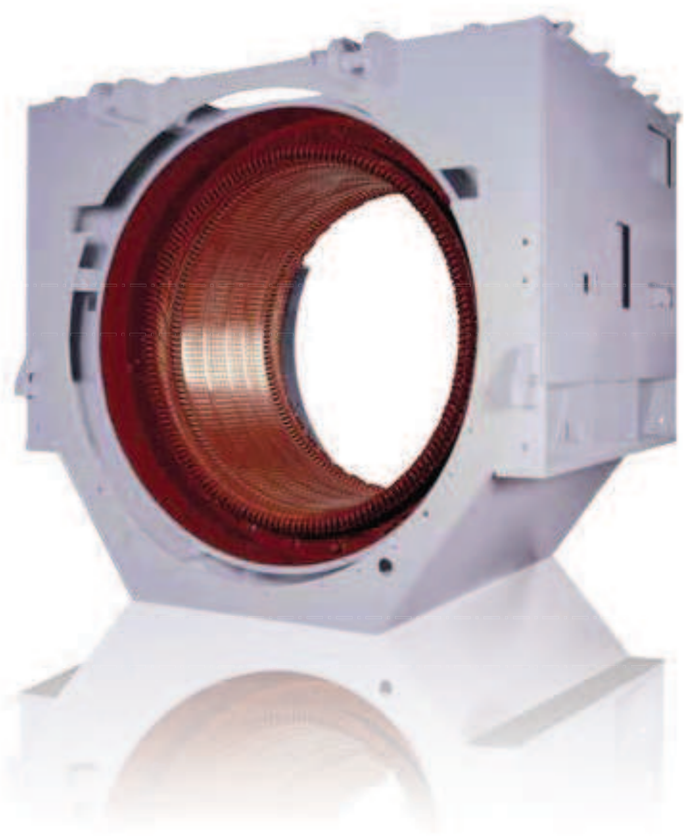
The rotor windings are either made of preformed enameled rectangular copper wire or flat copper. Proper supports between adjacent windings are used to ensure stability up to the rated overspeed. The rotor windings are made to match the insulation class of the stator. This ensures outstanding reliability and a long service life, even with asymmetric loads or under exceptional conditions.

Modular stator design enables performance to be optimized

Each application has its own specific requirements for motor performance. Our modular stator design allows us to precisely match the performance of every ABB synchronous motor to the needs of its application.

The stator core itself is built of stacked, high grade, low-loss laminated electrical steel, insulated on both sides with high quality insulating coating (heat-resistant inorganic coating is also available). The use of high grade core material increases efficiency and therefore reduces operating costs. Radial cooling ducts ensure uniform and effective cooling. The rigid stator construction transmits all forces via the frame to the foundation to minimize vibrations. The windings are insulated with Mica based tape. When the windings are in place, the complete stator undergoes vacuum pressure impregnation (VPI). The windings are class F insulated, which gives good thermal margins. This insulation system has been used very successfully over many years and in several thousand motors, and it provides reliability and a long operating life. Long-term reliability is also assured by the use of well proven methods for locking the coils into the slots and bracing the coil ends.

Robust frame ensures great stability and optimum dynamic behavior



For maximum flexibility, ABB synchronous motors are designed for horizontal, inclined or vertical mounting (vertical mounting available for motors with eight or more poles). The robust frame transfers dynamic and static stresses directly to the foundation, reducing vibration and contributing to the overall excellent performance of the motor.

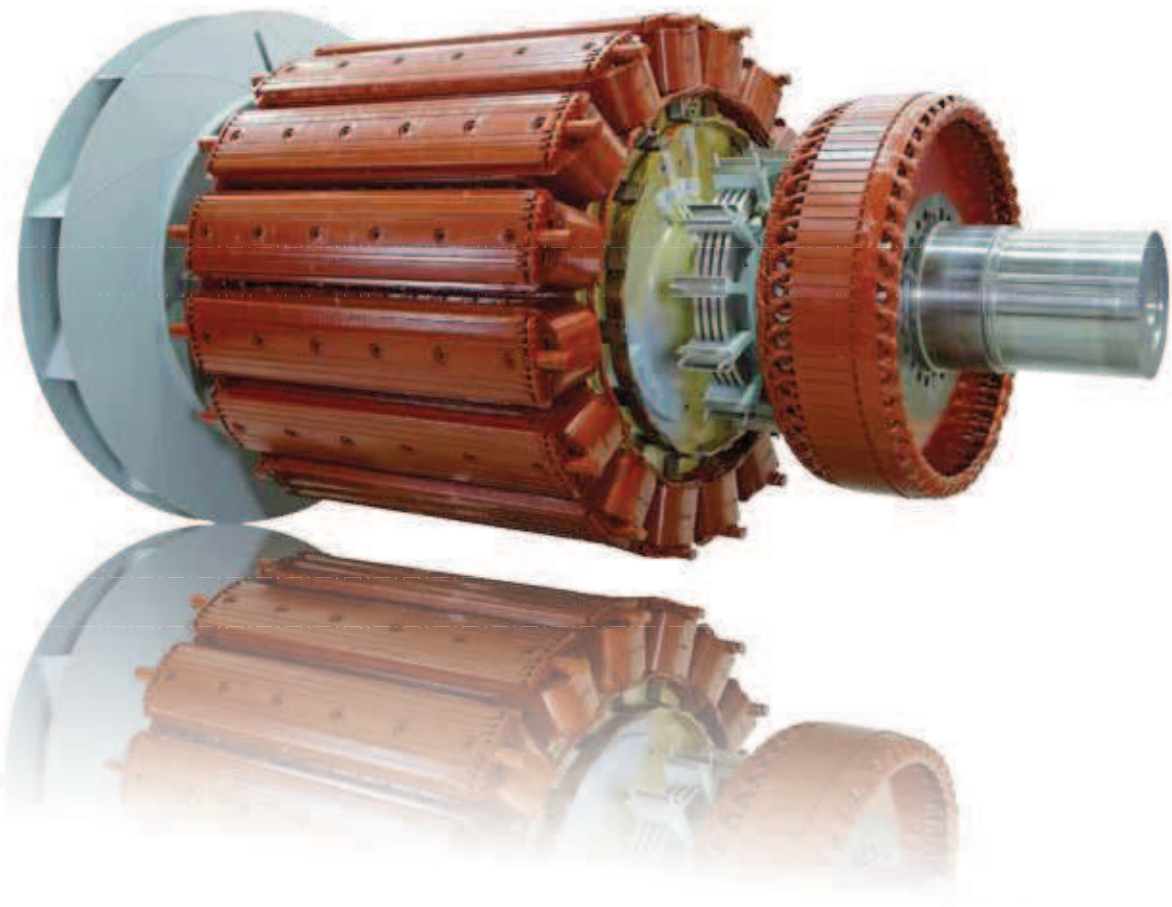
We can supply motors – even up to the largest sizes and outputs – as complete, ready-to-install units (in some cases the heat exchanger or terminal box has to be removed prior to shipment). This means that no further on-site assembly is needed, which substantially reduces installation times and cuts the risk that something could go wrong during installation.

Our R&D team works closely with manufacturers of driven equipment, using FEM and dynamic animation techniques, to analyze vibration models, test critical parts and verify that hazardous mechanical resonances will not occur in the motor.

Corrosion protection

Our motors are designed and built to withstand the relevant environmental conditions. All surfaces made of steel, aluminum alloy or cast iron are treated in accordance with the chosen paint system. Selection of a suitable paint system gives reliable anti-corrosion protection even under the most severe environmental conditions. For moderate indoor conditions the standard finish is moisture-proof in accordance with the relevant standards. Solvent free paints are used wherever possible in order to minimize environmental impacts.

The right excitation method for every application



At ABB we take care to ensure that the excitation system meets the very high overall standards of reliability that we have set for our synchronous motors.

For fixed speed applications and variable speed applications with less demanding dynamic control requirements, a brushless exciter and automatic voltage regulator are generally provided. The brushless system has no wearing parts, and the external excitation power requirement is low.

The brushless exciter is a separate AC generator mounted on the motor shaft at the non-drive end. In most fixed speed motors the field winding is DC fed; in variable speed motors (and fixed speed motors with LCI starting) the field winding is AC fed. The exciter is vacuum pressure impregnated using the MCI method, ensuring that the windings are sealed and secured. The advanced and yet straightforward design has a low component count and effective protection functions, and it offers high reliability and easy access for maintenance.

For variable speed applications where very fast and accurate speed or torque control are required, the motor is generally equipped with brushes and a slip ring unit to allow excitation and control of the motor from the frequency converter. The slip rings are mounted on the motor shaft with access via removable inspection covers. In general the slip rings and mounting flange or hub are made of steel, and they are normally mounted as a single unit. Slip ring units with brass rings, as well as split flange mounted units, are available on request. The slip ring unit is fitted with brass connection pins to facilitate installation.

No excitation system is needed for variable speed motors with permanent magnet rotors.

Higher speed motors (four and six poles) use a compact, brushless exciter unit mounted on the rotor shaft outboard of the bearings. No independent support or alignment is required. The high level of field forcing delivers improved system performance, which increases the production of reactive power and is beneficial when faults arise in the supply network.

Lower speed motors (eight or more poles) typically have a brushless exciter unit mounted inside the motor enclosure.

Excitation control

The motor excitation control panel can be supplied in a variety of basic formats. It houses the excitation equipment, protection system and logic functions for starting. Various options are available on request.

We offer a wide range of instrumentation and control equipment to protect synchronous motors and ensure excellent reliability and availability, and extended product lifetimes.

Integration with plant automation systems

The motor excitation control panel can, as an option, be adapted for immediate integration into a superior management and supervisory system. Communication via modem can also be supplied to facilitate remote support.

Effective and uniform cooling of the complete motor

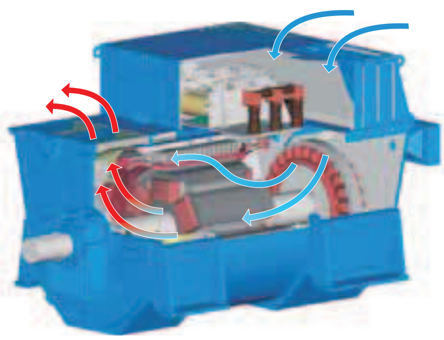
With a wide range of cooling methods available, the optimum system can be selected for the motor's operating and environmental conditions. Whichever method is chosen, it will provide effective cooling of the complete motor. The three most commonly used cooling arrangements are air-to-water, air-to-air and open air.

Air-to-water closed circuit cooling
The cooling air circulates in a closed circuit through the active parts of the motor and then through an air-to-water heat exchanger. This cooling method is especially recommended if the cooling water is located nearby. This configuration is an ideal solution for situations where closed circuit cooling is required due to installation outdoors, installation in a hazardous area, or whenever the quality of the surrounding air is not otherwise suitable for direct cooling. It is also ideal for installations in machine rooms with limited ventilation, such as on board ships or in pumping stations which are fully enclosed.

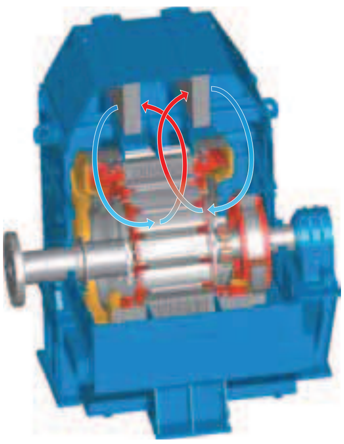
Air-to-air closed circuit cooling
The cooling air circulates in a closed circuit through the active parts of the motor and through an air-to-air heat exchanger. This solution is generally used in situations where a closed circuit cooling system – such as air-to-water cooling – is required but water is not readily available. This cooling arrangement requires an additional shaft-mounted or separate electric fan to ensure sufficient air flow through the cooler.

Open air cooling
Open air cooling can be used where the air in the immediate environment is relatively clean and there is adequate air circulation. The cooling air is typically drawn in through filters, passed through the active parts of the motor, and then exhausted back to the environment. If the machine room ventilation system cannot compensate for the temperature gradient, the motor air outlet can be ducted to exhaust the air outdoors.

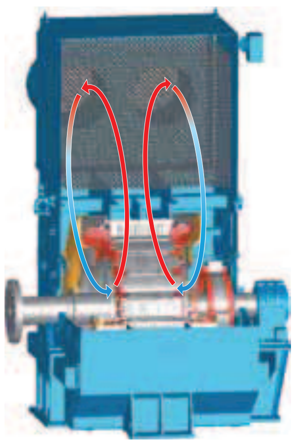
Enclosure protection classes
The motor enclosures feature protection in classes IP23, IP44, IP54 and IP55 (totally enclosed), or equivalent NEMA protection classes. Motors are also available for hazardous areas in accordance with IEC/ATEX or NEC regulations (non-sparking or pressurized construction).



An open air cooled motor (IC0A1) with drip proof protection (IP23)



A totally enclosed motor (IP54) using an air-to-water heat exchanger (IC8A1W7)



A totally enclosed motor (IP54) using an air-to-air heat exchanger (IC6A1A6)

Proven insulation system delivers ultimate reliability

ABB synchronous motors use the MICADUR® Compact Industry (MCI) insulation system, which is based on the vacuum pressure impregnation (VPI) method. The VPI and curing of the completely wound and connected stator winding with a specially formulated epoxy resin ensures a sealed and homogenous insulation system. This results in high dielectric strength, excellent heat transfer, and the elimination of hazardous internal partial discharges.

We have been using the MCI system for more than 30 years. It has been used on tens of thousands of our larger motors and generators, which are operating successfully all over the world. No primary insulation failures due to thermal aging have been experienced. Thermal lifetime tests performed on the MCI system show that its endurance substantially exceeds IEC and IEEE requirements.

MCI insulated windings require very little maintenance. In most cases it is only necessary to take steps to prevent the ingress of moisture or dirt during periods when the motor is not operating, as this could reduce the cooling ability of the winding.

The systematic VPI process is highly effective:

- High vacuum cycle – removes air and moisture from the voids and pores of the insulation.
- Highly stable epoxy resin – ensures superior protection under the most difficult environmental conditions (against lubricants, oil, moisture, common solvents, chemically aggressive gases, abrasive dust, tropical climate, etc.).
- High pressure cycle – forces the resin into even the smallest pores.
- Oven curing – after the VPI process has been completed, stators and rotors are cured in an oven at high temperature. This produces very strong and stable insulation with high mechanical and electrical strength. This is especially important in order to resist inadvertent high stresses from out-of-phase synchronization, transients and short circuits. Even the largest wound stators are impregnated as complete units. This ensures that both the insulation and the mechanical properties of the windings are excellent – which means that they can withstand vibrations induced by the driven equipment and the mechanical stresses caused by transients such as short circuits.

Stator winding and insulation classes

Medium and high voltage windings up to 15 000 V are made of form wound rectangular copper wire insulated with multiple layers of glass-fiber reinforced mica-tape.

All materials used, including the VPI resin, exceed the requirements of thermal class F. After insertion into the slots, the coils are firmly held in place by means of slot wedges and surge ropes at the coil heads prior to the VPI treatment. The completed process assures a long and trouble-free operating life.

High quality sleeve bearings for trouble-free operation

ABB synchronous motors use quality sleeve bearings that withstand high levels of vibration and offer excellent performance. The bearings provide the same high levels of reliability under static as well as dynamic (radial and axial) loads. Their excellent heat transfer capability makes them equally suitable for low and high speed applications.

The choice of bearing arrangement and type is based on the application, radial and axial loads, rotation speed, coupling type, and customer preferences. Operating conditions such as ambient temperature, air cleanliness, vibration levels and shocks affecting the bearings are also taken into account.

End-shield mounted bearings are always used in higher speed (four and six pole) motors. Pedestal mounted bearings are generally used for the largest frame sizes. Motors with pedestal bearings are as easy to mount and align as those with end-shield mounted bearings. The motors are normally delivered ready assembled and require no further assembly on site. Separate pedestal bearing motors are often mounted on a common base frame.

Sleeve bearings last as long as the expected life of the motor, provided that the operating conditions and maintenance intervals are as specified.

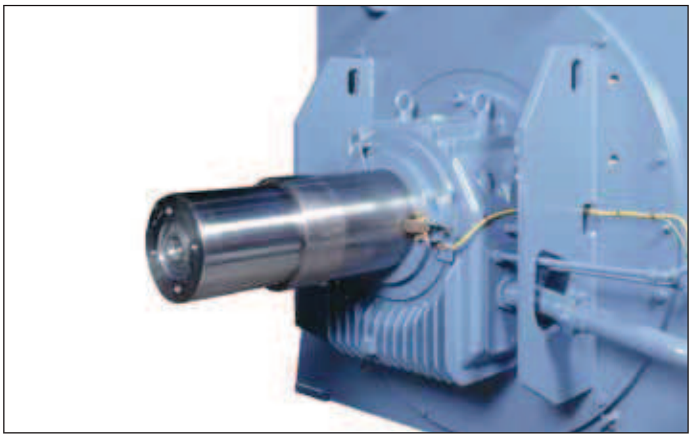
The bearing housing is designed to permit easy access for inspection and maintenance. The bearings are insulated from the motor frame to eliminate circulating currents in the shaft, and the shaft can be earthed. The bearings are sealed against oil leakage with labyrinth seals. Sleeve bearings are designed to be insensitive to misalignment and to permit large axial play.

Lubrication

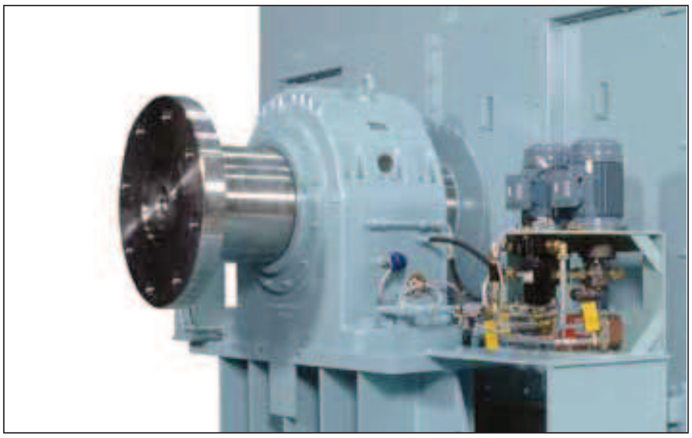
In some cases the bearings are self-lubricated by means of an oil ring, which picks up the lubricating oil and transfers it directly to the shaft, forming an independent and highly reliable lubrication system.

In applications involving large loads, high speeds, high ambient temperature or where the motor is mounted in an inclined position, an external oil cooling and circulation system may be necessary, unless the oil is supplied direct from the lubrication system of the driven equipment. In certain applications which run at slow speeds, a jack-up system may be necessary for starting.

Hydrostatic jacking oil systems are available for low-speed applications and, in specific situations, for use during motor start-up/shut down.

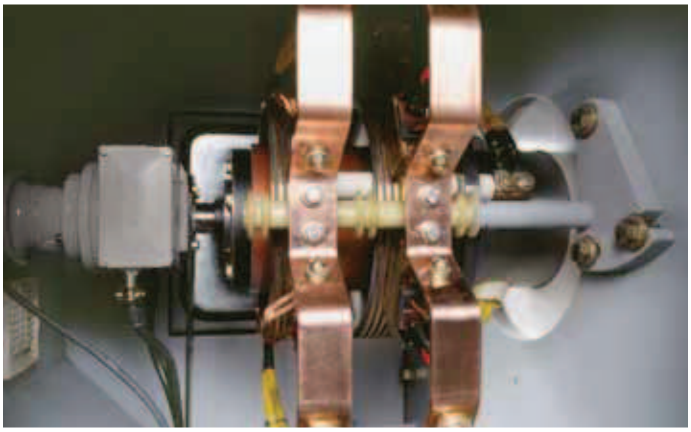


Flange mounted sleeve bearing



Pedestal mounted sleeve bearing

Comprehensive range of accessories



Accessories

We offer a large selection of accessories, eg for measuring, protection, termination, lubrication and mounting of the motor. Accessories include PT-100 sensors, earth fault protection relays, surge arrestors, CTs, rotor telemetrics, sole plates and anchor bolts. Certain accessories are included as standard, depending on the size and type of motor.

Terminal boxes

A separate main terminal box is mounted on the side of the motor, featuring bus bars outside the motor frame and allowing connections from any specified direction. The neutral terminal box is typically mounted on the opposite side of the motor from the main terminal box. For auxiliary and instrument cables, separate auxiliary terminal boxes are supplied as required.

Testing is fully integrated into manufacture

Testing forms an integral part of our manufacturing process. Tests – including quality monitoring, inspections and insulation reliability evaluations – are performed on components as they progress from one manufacturing stage to the next. In addition, every motor undergoes a comprehensive set of final tests before dispatch in order to verify that it meets the customer's requirements in all respects. The results of this final test are compiled into a report which is supplied to the customer once testing is completed.

All tests are performed according to IEC 60034 unless otherwise specified. Testing according to NEMA MG 1, IEEE-115 or classification society requirements is available on request.

Routine tests

The routine test program is performed on every motor and is included in the price of the motor.

Type tests

Type tests are performed in addition to the routine tests. They are normally performed on one machine in a series of motors not previously manufactured, or at the customer's request.

Special tests

Special tests may be conducted to verify performance in special conditions. They may, for example, be based on customer specifications, hazardous area or marine classification society requirements.

Pro-active services for optimum performance and extended lifetime

Synchronous motors always play a critical role in the plants where they operate, making availability and reliability the top priorities. We offer a complete portfolio of services to maximize the availability, reliability and performance of ABB synchronous motors. Our worldwide organization and network of selected partners ensure that we can respond quickly and support customers wherever they are located.

Our service offering covers the whole product life cycle, from consulting, installation and commissioning, through diagnosis, maintenance, spare parts and repairs, to migration and upgrades. Training for customer personnel is also available.

ABB's Life Cycle Management Plan for motors and generators prevents equipment failure due to component aging. The recommended maintenance program for ABB synchronous motors consists of four levels (L1 – L4) spaced at intervals over the product's lifetime. The age of the motor and ambient conditions in which it operates determine when each maintenance process should be undertaken. The service program can be adapted as necessary to meet specific requirements.

We also offer specialized tools such as ABB LEAP (ABB Life Expectancy Analysis Program), which is a diagnostic tool for assessing the condition of the stator winding insulation. Testing can be performed during the normal L1 – L4 maintenance procedures, and the results provide a basis on which specific preventive service actions can be planned. Preventive service measures reduce unplanned – and therefore expensive – shutdowns caused by failures that could have been foreseen.

Our synchronous motors are designed to provide easy access for service and maintenance, and the services we offer will ensure the motors deliver trouble-free operation over an extended lifetime.

Reliable operation in a wide range of applications

Typical industries served: 1 Air separation | 2 Cement | 3 Chemical, oil and gas | 4 Marine | 5 Metals and minerals | 6 OEMs and system integrators | 7 Power generation | 8 Pulp and paper | 9 Water and wastewater

ABB synchronous motors deliver efficient and reliable operation in many different applications. We have extensive experience in designing and building motors that precisely match the customer's needs across a range of different industries.

We have supplied motors for:

- Chemical, oil and gas: compressors, pumps and extruders
- Marine and offshore: variable speed motors in azimuthing propulsors and shaft line applications
- Metals and minerals: rolling mills, hoists, processing lines, SAG and ball mills, and blowers
- Power utilities: pumps and condensers
- Pulp and paper: chippers, refiners and grinders
- Water and waste water: pumps
- Air separation: compressors
- Special applications: wind tunnel motors and MG sets

Proven performance around the world

1 Azipod® propulsion unit | 2 Mine hoist motors | 3 Refiner motor | 4 Rolling mill motor (twin drive) | 5 Hydrogen gas compressor motors | 6 Medium section motors

Total offer of motors, generators and mechanical power transmission products with a complete portfolio of services

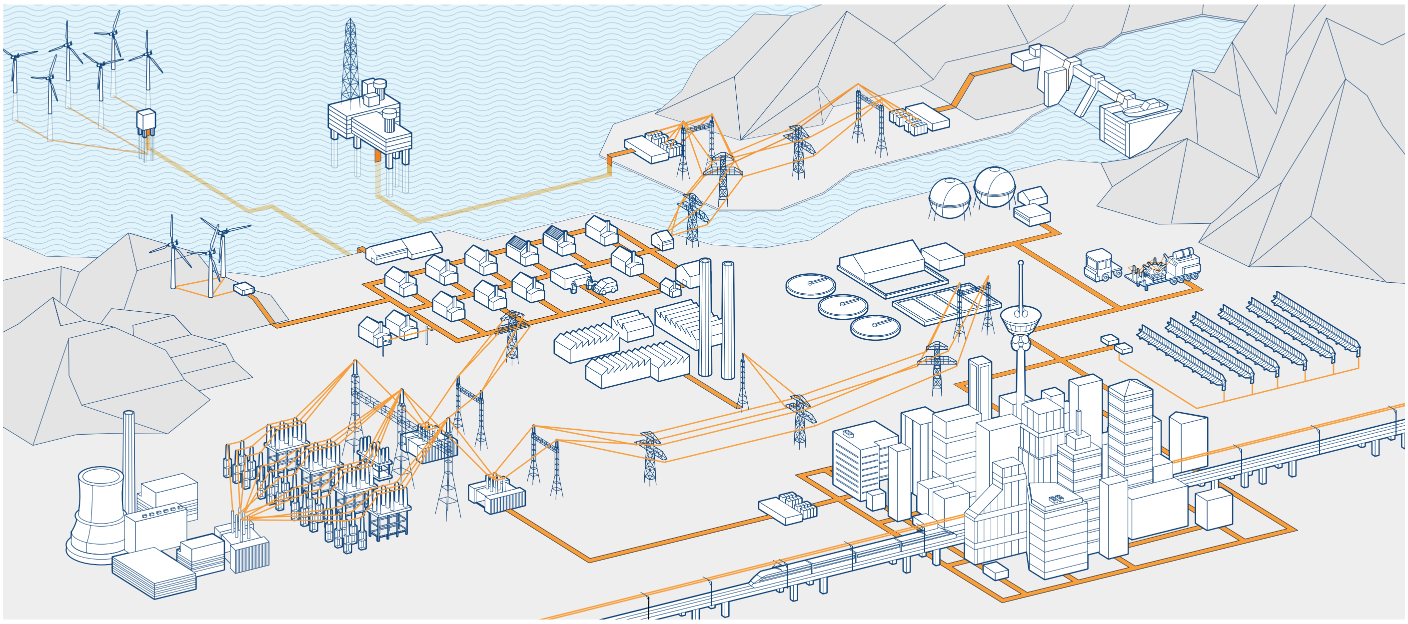


ABB is the leading manufacturer of low, medium and high voltage motors and generators, mechanical power transmission products with an offering of a complete portfolio of services. Our in-depth knowledge of virtually every type of industrial processing ensures we always specify the best solution for your needs.

Low and high voltage IEC induction motors
- Process performance motors
- General performance motors
- High voltage cast iron motors
- Induction modular motors
- Slip-ring modular motors
- Synchronous reluctance motors

Low and medium voltage NEMA motors
- Steel frame open drip proof (ODP) motors
- Weather protected, water cooled, fan ventilated
- Cast iron frame (TEFC)
- Air to air cooled (TEAAC) motors

Motors and generators for explosive atmospheres
- IEC and NEMA motors and generators, for all protection types

Synchronous motors

Synchronous generators
- Synchronous generators for diesel and gas engines
- Synchronous generators for steam and gas turbines

Wind power generators

Generators for small hydro

Other motors and generators
- Brake motors
- DC motors and generators
- Gear motors
- Marine motors and generators
- Single phase motors
- Motors for high ambient temperatures
- Permanent magnet motors and generators
- High speed motors
- Smoke extraction motors
- Wash down motors
- Water cooled motors
- Generator sets
- Roller table motors
- Servo motors
- Traction motors

Life cycle services
- Installation and commissioning
- Service contracts
- Preventive maintenance
- Spare parts
- Diagnosis
- Repair and refurbishment
- Site survey and overhaul
- Replacement motors and generators
- Technical support and consulting
- Training

Mechanical power transmission components, bearings, gears

Contact us

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9AKK105576 EN 12-2011

Power and productivity
for a better world™

ANEXO 2

INFORMES NAVCAD RESISTENCIA AL AVANCE (Rt)

Resistance

9 dic 2016 07:07
HydroComp NavCad 2014

Project ID **LNG CAOREGON**
Description
File name **LNG TANKER C6.hcnc**

Analysis parameters

Vessel drag	ITTC-78 (CT)	Added drag	
Technique:	[Calc] Prediction	Appendage:	[Off]
Prediction:	Holtrop	Wind:	[Off]
Reference ship:		Seas:	[Off]
Model LWL:		Shallow/channel:	[Off]
Expansion:	Custom	Towed:	[Off]
Friction line:	ITTC-57	Margin:	[Off]
Hull form factor:	[Off]	**Water properties**	
Speed corr:		Water type:	Salt
Spray drag corr:	[Off]	Density:	1026,00 kg/m3
Corr allowance:	0,000000	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	0,21	0,75	6,15	3,97	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
14,00	0,137	0,332	1,71e9	0,001434	1,000	0,000930	0,000000	0,000000	0,002364
15,00	0,147	0,356	1,83e9	0,001422	1,000	0,000945	0,000000	0,000000	0,002367
16,00	0,156	0,379	1,95e9	0,001411	1,000	0,000973	0,000000	0,000000	0,002384
17,00	0,166	0,403	2,08e9	0,001401	1,000	0,001017	0,000000	0,000000	0,002418
18,00	0,176	0,427	2,20e9	0,001391	1,000	0,001078	0,000000	0,000000	0,002469
19,00	0,186	0,450	2,32e9	0,001383	1,000	0,001157	0,000000	0,000000	0,002540
20,00	0,196	0,474	2,44e9	0,001374	1,000	0,001256	0,000000	0,000000	0,002630
+ 21,00 +	0,205	0,498	2,56e9	0,001366	1,000	0,001376	0,000000	0,000000	0,002742
22,00	0,215	0,522	2,69e9	0,001359	1,000	0,001512	0,000000	0,000000	0,002871
23,00	0,225	0,545	2,81e9	0,001352	1,000	0,001669	0,000000	0,000000	0,003020

	RESISTANCE								
SPEED [kt]	RBARE [kN]	RAPP [kN]	RWIND [kN]	RSEAS [kN]	RCHAN [kN]	RTOWED [kN]	RMARGIN [kN]	RTOTAL [kN]	
14,00	968,73	0,00	0,00	0,00	0,00	0,00	0,00	968,73	
15,00	1113,67	0,00	0,00	0,00	0,00	0,00	0,00	1113,67	
16,00	1276,43	0,00	0,00	0,00	0,00	0,00	0,00	1276,43	
17,00	1461,21	0,00	0,00	0,00	0,00	0,00	0,00	1461,21	
18,00	1672,99	0,00	0,00	0,00	0,00	0,00	0,00	1672,99	
19,00	1917,32	0,00	0,00	0,00	0,00	0,00	0,00	1917,32	
20,00	2200,29	0,00	0,00	0,00	0,00	0,00	0,00	2200,29	
+ 21,00 +	2528,90	0,00	0,00	0,00	0,00	0,00	0,00	2528,90	
22,00	2906,10	0,00	0,00	0,00	0,00	0,00	0,00	2906,10	
23,00	3341,32	0,00	0,00	0,00	0,00	0,00	0,00	3341,32	

	EFFECTIVE POWER		OTHER			
SPEED [kt]	PEBARE [kW]	PETOTAL [kW]	CTLR	CTLT	RBARE/W	
14,00	6977,0	6977,0	0,01824	0,04637	0,00087	
15,00	8593,8	8593,8	0,01854	0,04643	0,00100	
16,00	10506,4	10506,4	0,01910	0,04678	0,00115	
17,00	12779,1	12779,1	0,01995	0,04743	0,00131	
18,00	15491,8	15491,8	0,02115	0,04844	0,00150	
19,00	18740,8	18740,8	0,02270	0,04983	0,00172	
20,00	22638,6	22638,6	0,02465	0,05160	0,00197	
+ 21,00 +	27320,6	27320,6	0,02699	0,05380	0,00227	
22,00	32890,5	32890,5	0,02967	0,05633	0,00261	
23,00	39535,3	39535,3	0,03273	0,05925	0,00300	

Resistance

9 dic 2016 07:07
HydroComp NavCad 2014

Project ID **LNG CAOREGON**
Description
File name **LNG TANKER C6.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:		**282,200 m**	*LCG fwd TR:*	*[XCG/LP 0,000]*	***0,000 m***
Max beam on WL:	[LWL/BWL 6,148]	**45,900 m**	*VCG below WL:*		***0,000 m***
Max molded draft:	[BWL/T 3,967]	**11,570 m**	*Aft station (fwd TR):*		***0,000 m***
Displacement:	[CB 0,739]	**113663,00 t**	*Deadrise:*		***0,00 deg***
Wetted surface:	[CS 2,755]	**15402,5 m2**	*Chine beam:*		***0,000 m***
ITTC-78 (CT)			*Chine ht below WL:*		***0,000 m***
LCB fwd TR:	[XCB/LWL 0,514]	**145,154 m**	*Fwd station (fwd TR):*		***0,000 m***
LCF fwd TR:	[XCF/LWL 0,497]	**140,259 m**	*Deadrise:*		***0,00 deg***
Max section area:	[CX 0,979]	**520,0 m2**	*Chine beam:*		***0,000 m***
Waterplane area:	[CWP 0,830]	**10755,6 m2**	*Chine ht below WL:*		***0,000 m***
Bulb section area:		**9,6 m2**	*Propulsor type:*		***Propeller***
Bulb ctr below WL:		**2,979 m**	*Max prop diameter:*		***9000,0 mm***
Bulb nose fwd TR:		**291,000 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:		**24,00 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***

Resistance

9 dic 2016 07:07
HydroComp NavCad 2014

Project ID **LNG CAOREGON**
Description
File name **LNG TANKER C6.hcnc**

Appendage data

General	
Definition:	**Component**
Percent of hull drag:	**0,00 %**
Planing influence	
LCE fwd TR:	**0,000 m**
VCE below WL:	**0,000 m**
Shafting	
Count:	**1**
Max prop diameter:	**9000,0 mm**
Shaft angle to WL:	**0,00 deg**
Exposed shaft length:	**0,000 m**
Shaft diameter:	**1,460 m**
Wetted surface:	**0,0 m2**
Strut bossing length:	**4,000 m**
Bossing diameter:	**3,740 m**
Wetted surface:	**47,0 m2**
Hull bossing length:	**42,160 m**
Bossing diameter:	**6,500 m**
Wetted surface:	**860,9 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:	**1**
Rudder location:	**Behind propeller**
Type:	**Balanced foil**
Root chord:	**5,570 m**
Tip chord:	**5,000 m**
Span:	**11,000 m**
T/C ratio:	**0,150**
LE sweep:	**7,00 deg**
Projected area:	**61,3 m2**
Wetted surface:	**123,0 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:	**1**
Diameter:	**2,850 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

9 dic 2016 07:07
HydroComp NavCad 2014

Project ID **LNG CAOREGON**
Description
File name **LNG TANKER C6.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 3
INFORMES NAVCAD
PROPULSOR DE 5 PALAS

Propulsion

10 dic 2016 11:33
HydroComp NavCad 2014

Project ID **LNG CAOREGON**
Description
File name **LNG TANKER C6.hcnc**

Analysis parameters

Hull-propulsor interaction		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:	
Corrections		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 kg/m3
Roughness [mm]:		Viscosity:	1,18920e-6 m2/s
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	0,21	0,75	6,15	3,97
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 [%]
14,00	6977,0	0,4185	0,2085	0,9950	53	10243,0	---	20,5
15,00	8593,8	0,4177	0,2085	0,9950	57	12617,2	---	25,2
16,00	10506,4	0,4171	0,2085	0,9950	61	15450,1	---	30,9
17,00	12779,1	0,4164	0,2085	0,9950	66	18855,1	---	37,7
18,00	15491,8	0,4159	0,2085	0,9950	70	22976,4	---	46,0
19,00	18740,8	0,4153	0,2085	0,9950	74	27993,5	---	56,0
20,00	22638,6	0,4148	0,2085	0,9950	79	34122,5	---	68,2
+ 21,00 +	27320,6	0,4143	0,2085	0,9950	84	41632,7	---	83,3
22,00	32890,5	0,4139	0,2085	0,9950	90	50744,3	---	101,5
23,00	39535,3	0,4134	0,2085	0,9950	96	61873,4	---	123,7

	POWER DELIVERY							
SPEED [kt]	RPMPROP [RPM]	QPROP [kN·m]	QENG [kN·m]	PDPROP [kW]	PSPROP [kW]	PSTOTAL [kW]	PBTOTAL [kW]	TRANSP
14,00	53	1703,98	1703,98	9592,9	9889,6	9889,6	10243,0	783,8
15,00	57	1959,06	1959,06	11827,6	12193,4	12193,4	12617,2	681,7
16,00	61	2244,58	2244,58	14494,6	14942,9	14942,9	15450,1	593,8
17,00	66	2567,39	2567,39	17700,9	18248,3	18248,3	18855,1	517,0
18,00	70	2935,59	2935,59	21582,4	22249,9	22249,9	22976,4	449,2
19,00	74	3358,29	3358,29	26308,4	27122,0	27122,0	27993,5	389,2
20,00	79	3845,38	3845,38	32082,7	33075,0	33075,0	34122,5	336,1
+ 21,00 +	84	4408,25	4408,25	39159,5	40370,6	40370,6	41632,7	289,2
22,00	90	5051,65	5051,65	47746,5	49223,2	49223,2	50744,3	248,6
23,00	96	5790,98	5790,98	58216,7	60017,2	60017,2	61873,4	213,2

	EFFICIENCY				THRUST	
SPEED [kt]	EFFO	EFFG	EFFOA	MERIT	THRPROP [kN]	DELTHR [kN]
14,00	0,5371	0,9655	0,7055	0,55528	1223,96	968,73
15,00	0,5372	0,9664	0,7048	0,55513	1407,08	1113,66
16,00	0,5366	0,9672	0,7031	0,55584	1612,73	1276,42
17,00	0,5350	0,9678	0,7003	0,55749	1846,20	1461,21
18,00	0,5324	0,9684	0,6963	0,56014	2113,76	1672,98
19,00	0,5289	0,9689	0,6910	0,56378	2422,48	1917,32
20,00	0,5244	0,9693	0,6845	0,56834	2780,01	2200,29
+ 21,00 +	0,5189	0,9697	0,6767	0,57375	3195,20	2528,90
22,00	0,5127	0,9700	0,6682	0,57968	3671,77	2906,09
23,00	0,5058	0,9700	0,6587	0,58613	4221,68	3341,32

Propulsion

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Project ID **LNG CAOREGON**
Description
File name **LNG TANKER C6.hcnc**

Prediction results [Propulsor]

	PROPULSOR COEFS								
SPEED [kt]	J	KT	KQ	KTJ2	KQJ3	CTH	CP	RNPROP	
14,00	0,5220	0,2288	0,03539	0,83954	0,24879	2,1379	4,0006	6,04e7	
15,00	0,5222	0,2287	0,03538	0,83865	0,24845	2,1356	3,9952	6,48e7	
16,00	0,5213	0,2291	0,03543	0,84287	0,25002	2,1463	4,0203	6,93e7	
17,00	0,5194	0,2301	0,03555	0,85289	0,25373	2,1719	4,0801	7,40e7	
18,00	0,5162	0,2317	0,03575	0,86928	0,25984	2,2136	4,1784	7,89e7	
19,00	0,5119	0,2338	0,03602	0,89247	0,26857	2,2727	4,3187	8,40e7	
20,00	0,5064	0,2366	0,03636	0,92272	0,28007	2,3497	4,5036	8,94e7	
+ 21,00 +	0,4998	0,2399	0,03677	0,96035	0,29458	2,4455	4,7369	9,52e7	
22,00	0,4924	0,2435	0,03722	1,004	0,31166	2,5566	5,0116	1,01e8	
23,00	0,4844	0,2474	0,03771	1,0546	0,33184	2,6856	5,336	1,08e8	

	CAVITATION								
SPEED [kt]	SIGMAV	SIGMAN	SIGMA07R	TIPSPEED [m/s]	MINBAR	PRESS [kPa]	CAVAVG [%]	CAVMAX [%]	PITCHFC [mm]
14,00	18,79	5,12	1,00	25,21	0,450	20,16	2,0	2,0	6510,0
15,00	16,32	4,45	0,87	27,03	0,488	23,17	2,0	2,0	6510,7
16,00	14,31	3,89	0,76	28,91	0,530	26,56	2,0	2,0	6507,5
17,00	12,65	3,41	0,67	30,87	0,578	30,41	2,0	2,0	6499,7
18,00	11,26	3,00	0,59	32,92	0,632	34,81	2,0	2,0	6487,4
19,00	10,09	2,64	0,52	35,08	0,695	39,90	2,0	2,0	6470,3
20,00	9,09	2,33	0,46	37,36	0,768	45,79	2,3	2,3	6448,9
+ 21,00 +	8,23	2,06	0,40	39,77	0,853	52,62	3,1	3,1	6423,3
22,00	7,49	1,82	0,36	42,32	0,951	60,47	4,2	4,2	6395,2
23,00	6,84	1,61	0,32	45,01	1,063	69,53 !	5,8	5,8	6364,4

Propulsion

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Project ID **LNG CAOREGON**
Description
File name **LNG TANKER C6.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:		**282,200 m**	*LCG fwd TR:*	*[XCG/LP 0,000]*	***0,000 m***
Max beam on WL:	[LWL/BWL 6,148]	**45,900 m**	*VCG below WL:*		***0,000 m***
Max molded draft:	[BWL/T 3,967]	**11,570 m**	*Aft station (fwd TR):*		***0,000 m***
Displacement:	[CB 0,739]	**113663,00 t**	*Deadrise:*		***0,00 deg***
Wetted surface:	[CS 2,755]	**15402,5 m2**	*Chine beam:*		***0,000 m***
ITTC-78 (CT)			*Chine ht below WL:*		***0,000 m***
LCB fwd TR:	[XCB/LWL 0,514]	**145,154 m**	*Fwd station (fwd TR):*		***0,000 m***
LCF fwd TR:	[XCF/LWL 0,497]	**140,259 m**	*Deadrise:*		***0,00 deg***
Max section area:	[CX 0,979]	**520,0 m2**	*Chine beam:*		***0,000 m***
Waterplane area:	[CWP 0,830]	**10755,6 m2**	*Chine ht below WL:*		***0,000 m***
Bulb section area:		**9,6 m2**	*Propulsor type:*		***Propeller***
Bulb ctr below WL:		**2,979 m**	*Max prop diameter:*		***9000,0 mm***
Bulb nose fwd TR:		**291,000 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:		**24,00 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 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:	**Custom**
Reference prop:				Scale correction:	**None**
Blade count:		**5**		KT multiplier:	**1,000**
Expanded area ratio:		**0,9544**	**[Size]**	KQ multiplier:	**1,000**
Propeller diameter:		**9000,0 mm**	**[Keep]**	Blade T/C [0.7R]:	**0,00**
Propeller mean pitch:	[P/D 0,9133]	**8220,0 mm**	**[Size]**	Roughness:	**0,00 mm**
Hub immersion:		**6900,0 mm**		Cav breakdown:	**Off**
Engine/gear				**Design condition**	
Engine data:		**Untitled Engine Obje...**		Max prop diam:	**9000,0 mm**
Rated RPM:		**250 RPM**		Design speed:	**21,00 kt**
Rated power:		**50000,0 kW**		Reference power:	**50000,0 kW**
Gear efficiency:		**0,970**		Design point:	**1,000**
Load correction:		**On**		Reference RPM:	**86,0**
Gear ratio:		**1,000**	**[Keep]**	Design point:	**1,030**
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