ADVANCED PROPULSION SYSTEM – MID-TERM EXAM
16/11/2007 - 14:00-15:00

1. The axial wake of a large bulk carrier has been given below. Determine the upper limit of propeller rotation rate N (rpm) which is no risk of propeller excited vibration and cavitation according to the BMT's wake non-uniformity criteria (w_Δ, σ_{nI}) given in figure 1. (**15 Points**)

Given:

D =8.0 m (propeller diameter)
N = ? (Number of propeller revolution per minute - RPM)
Zp = 4.6 m. (shaft height from the base line)
Ta = 16.1 m (Draft at the aft perpendicular)
Vapour pressure ($P_a - P_v$) = 100 000 Pa
ρ = 1025 kg/m^3. (Density of sea water)
g = 9.80665 m/sn^2. (Acceleration of gravity)

$$\sigma_{nI} = \frac{P_a - P_v + P_H}{\frac{1}{2}\rho(\pi n D)^2}$$

$$P_H = Hydrostatic\ pressure\ at\ the\ propeller\ tip$$

$$w_\Delta = \left(\frac{\Delta w}{1 - \bar{w}}\right)_{1.0R}$$

The wake is given in terms of the ***velocity ratio's*** method.

Ang-r/R	0.30	0.40	0.50	0.60	0.70	0.80	0.90	0.95	1.00
0	0.116	0.129	0.142	0.147	0.147	0.147	0.137	0.129	0.119
10	0.133	0.144	0.151	0.155	0.158	0.162	0.167	0.170	0.174
20	0.152	0.160	0.163	0.167	0.170	0.178	0.191	0.200	0.210
30	0.166	0.175	0.174	0.178	0.183	0.192	0.210	0.223	0.238
40	0.178	0.181	0.181	0.186	0.195	0.208	0.234	0.253	0.276
50	0.185	0.188	0.183	0.194	0.212	0.235	0.274	0.301	0.333
60	0.187	0.190	0.188	0.211	0.247	0.285	0.339	0.374	0.413
70	0.189	0.195	0.200	0.243	0.303	0.359	0.427	0.465	0.506
80	0.190	0.203	0.226	0.291	0.374	0.448	0.522	0.560	0.597
90	0.191	0.216	0.264	0.348	0.449	0.533	0.609	0.643	0.675
100	0.190	0.232	0.308	0.406	0.514	0.603	0.677	0.707	0.733
110	0.189	0.246	0.349	0.455	0.564	0.655	0.726	0.752	0.774
120	0.187	0.255	0.378	0.490	0.599	0.691	0.759	0.783	0.802
130	0.181	0.256	0.392	0.509	0.622	0.716	0.784	0.806	0.823
140	0.176	0.251	0.387	0.508	0.627	0.730	0.802	0.824	0.839
150	0.171	0.238	0.363	0.485	0.611	0.726	0.807	0.831	0.848
160	0.167	0.220	0.321	0.438	0.570	0.701	0.797	0.826	0.847
170	0.169	0.196	0.261	0.363	0.499	0.669	0.792	0.824	0.845
180	0.157	0.162	0.175	0.239	0.376	0.663	0.847	0.869	0.869
mean	0.175	0.205	0.259	0.324	0.398	0.472	0.534	0.558	0.580

Here 0° – Top dead center – 180° – bottom death center

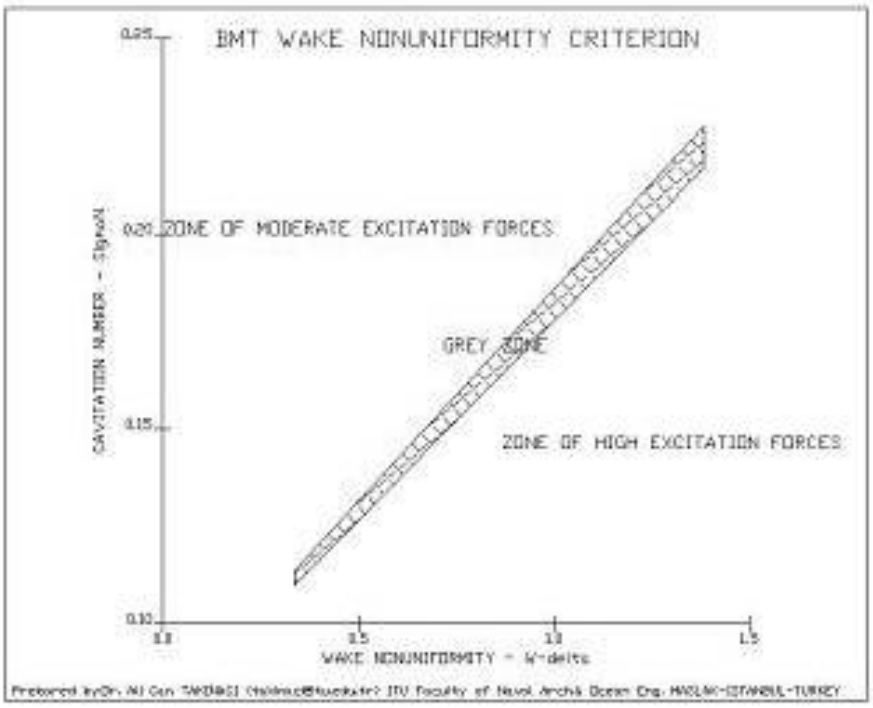

Figure 1. BMT 's wake nonuniformity criteria

2. A Motoryacht propeller has been given below. Determine the whole propeller weight excluding boss by taking 3% for blade fillets? (**5 Points**)

D =1.25 m (propeller diameter)
Z = 5 (number of blades)
ρ = 8600 kg/m^3. (Density of propeller material - bronze)
r, A = propeller radii and sectional areas referring Table 1

Table 1: Propeller radii and sectional areas

i	r (cm)	A (cm^2)
1	12.50	64.21
2	18.75	66.35
3	25.00	63.97
4	31.25	57.52
5	37.50	48.34
6	43.75	37.57
7	50.00	25.82
8	56.25	13.63
9	59.38	6.34
10	60.94	2.86
11	62.50	0.99

Good Luck! Dr. Ali Can Takinacı

SOLUTIONS

1. **a)** For finding rotation rate it should be calculated the parameter σ_{NI}. Therefore, from the wake data wake nonuniformity parameter w_Δ should be known.

From the wake data
$w_{1.0R}$=1-0.58 = 0.42
$w_{1.0max}$=0.869
$w_{1.0min}$=0.119

$$w_\Delta = \left(\frac{\Delta w}{1 - \bar{w}}\right)_{1.0R} = \left(\frac{0.869 - 0.119}{1 - 0.420}\right)_{1.0R} = 1.293 \approx 1.3$$

for w_Δ =1.3 the cavitation number σ_{NI} can be read off the figure 1 as around 0.22.

$$\sigma_{nI} = \frac{100000 + 9.80665 \times 1025 \times \left(16.10 - \frac{8.00}{2} - 4.60\right)}{\frac{1}{2} \times 1025 \times (\pi \times n \times 8.00)^2} = 0.22$$

From the equation n can be calculated as around **94 RPM** which is the upper limit of propeller rotation rate. Therefore suitable maine angine and reduction gear ratio can be chosen properly.

2. First, it should be obtained simple table for one blade as below. Then it should be multiplied by the number of blades, then fillets should be added to the total sum.

i	r(i) (cm)	Ax(i) (cm2)	m(i) (kg)
1	12.5	64.210	--
2	18.75	66.350	3.51
3	25	63.970	3.50
4	31.25	57.520	3.27
5	37.5	48.340	2.84
6	43.75	37.570	2.31
7	50	25.820	1.70
8	56.25	13.630	1.06
9	59.38	6.340	0.27
10	60.94	2.860	0.06
11	62.5	0.990	0.03

ρ= 8600 kg/m^3
m= 18.55 kg
M_{total}= m*5*1.03= 95.53329 kg