

FUNCTION: NAVIGATION (Management Level)

PAPER: ENGINEERING KNOWLEDGE, INSTRUMENTS & CONTROL SYSTEMS

NUMERICAL BASED ON FUEL CONSUMPTION/ INDICATOR

DIAGRAM/ POWER OUTPUT/ SLIP



Chief Mate-FG (Phase-II)

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: [SMART MARINER](https://www.youtube.com/channel/UC...) (Click to subscribe)



* Propeller

→ Diameter (D): The diameter of the propeller is the diameter of the circle or disc cut out by the blade tips.

→ Pitch (P): If the propeller is assumed to work in an unyielding fluid, then in one revolution of the shaft the propeller will move forward a distance which is known as pitch.

→ Pitch ratio (p): Pitch ratio or face pitch ratio is the face pitch divided by the diameter.

$$\text{Pitch ratio (p)} = \frac{\text{Pitch (P)}}{\text{Diameter (D)}} \text{ in meters}$$

$$p = \frac{P}{D}$$

→ Theoretical speed (V_T): It is the distance the propeller would advance in unit time if working in an unyielding fluid.

This is also known as propeller speed.

Thus, if the propeller turns at N rev/min

Then, $V_T = P \times N$ m/min

$P = \text{pitch}$, $N = \text{RPM}$

$$V_T = \frac{P \times N \times 60}{1852} \text{ Knots.}$$

→ Apparent slip: Since the propeller works in water, the ship's speed (V) will normally be less than the theoretical speed (V_T).
(observed speed) (engine speed)

The difference between the two speed is known as the apparent slip and is expressed as ratio or percentage of theoretical speed.

$$\text{Apparent slip speed} = V_T - V$$

$$\text{Apparent slip} = \frac{V_T - V}{V_T} \times 100\%$$

If V is greater than V_T

then Apparent slip will come negative.

→ Speed of advance (V_a): As a ship moves through the water at some speed (V), it drags the surrounding water with it. At the stern of the ship, this causes the wake to ~~follow~~ follow along with the ship

at a wake speed.

consequently, the propeller will experience a flow speed less than the ship speed. The speed of the ship relative to the wake is termed as speed of advance.

$$V_a = V - V_w, \text{ where } V_w = \text{wake speed}$$

$$V = \text{ship's speed.}$$

* The wake speed is often expressed as a fraction of the ship's speed

$$\text{wake fraction}(w) = \frac{V - V_a}{V}$$

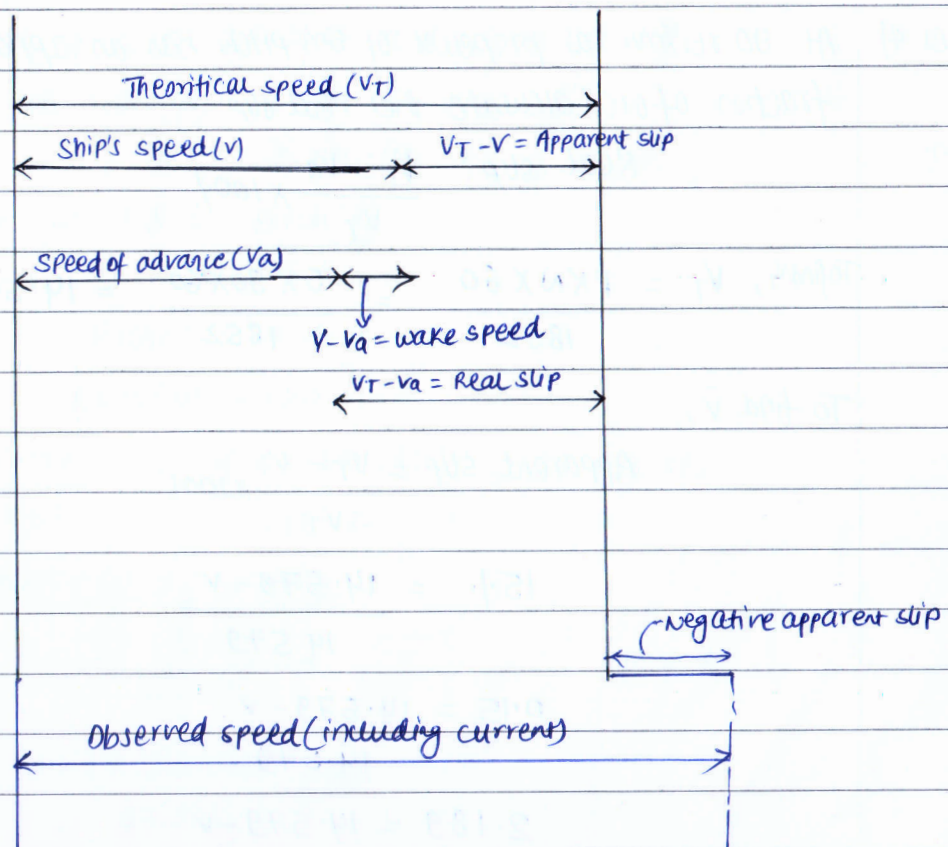
* The wave fraction may be obtained approximately from the expression

$$w = 0.5 C_b - 0.05, \text{ where } C_b = \text{Block coefficient.}$$

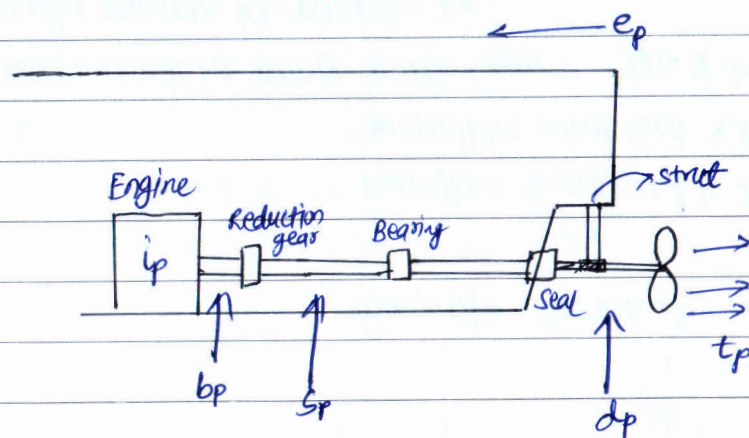
→ Real slip or true slip: It is the difference between the theoretical speed (V_T) and the speed of advance (V_a) is expressed as a ratio or percentage of the theoretical speed.

$$\text{Real slip speed} = V_T - V_a$$

$$\text{Real slip} = \frac{V_T - V_a}{V_T} \times 100\%$$



* Different types of power



- Indicated power (i_p): The theoretical power produced inside engine cylinders, calculated from the pressure-volume diagram before any mechanical losses is called indicated power (i_p)
- Brake power (b_p): The actual power available at the crankshaft which is less than the indicated speed due to mechanical losses from ~~the~~ friction and auxiliary components.
- Shaft power (s_p): The power available at the propeller shaft after reduction gear (if any) due to transmission losses through the gear system.
Note:- Shaft power is equal to brake power if there is no reduction gear.
- Delivered power (d_p): The power delivered to the propeller.
It is calculated by multiplying the shaft power by transmission efficiency of the propeller shafting system.
- Thrust power (t_p): The power that the propeller generates to produce thrust, which propels the ship forward. It is calculated by multiplying the delivered power by the propeller efficiency.
- Effective power (e_p): The power that is actually used to move the ship.
It is the product of the thrust power and the hull efficiency.

Formula

1) s_p or $b_p = i_p \times \text{mechanical efficiency}$

2) $d_p = s_p \times \text{transmission efficiency}$

3) $d_p = \text{torque} \times 2\pi n$ where, $n = \text{RPM}$

4) $t_p = d_p \times \text{propeller efficiency}$

5) $e_p = t_p \times \text{hull efficiency}$

6) $t_p = T \times v_a$, where, T = thrust in N and

v_a = Speed of Advance in m/sec.

7) $e_p = d_p \times QPC$, where, QPC = Quasi Propulsive coefficient.

8) $e_p = i_p \times \text{propulsive coefficient}$

$e_p = s_p \times \text{propulsive coefficient}$

OR

propulsive efficiency

$$g) \tan \theta = \frac{P}{2\pi r}$$

$$P = 2\pi r \tan \theta$$

→ Projected Area (A_p): It is the sum of blade areas projected on to a plane which is perpendicular to the axis of the screw.

→ Developed area: It is the actual area of driving face

It is of two types:

a) Clear of the boss (A_d)

b) Including the boss area (A_b)

→ Blade area ratio (BAR): It is the developed area excluding boss divided by the area of the circle cut out by the blade tips.

$$BAR = \frac{A_d}{\pi r^2} \text{ or } \frac{A_d}{\frac{\pi}{4} D^2}$$

→ Disk area ratio (DAR): It is the developed area including boss divided by the area of the circle cut out by the blade tips

$$DAR = \frac{A_b}{\pi r^2} \text{ or } \frac{A_b}{\frac{\pi}{4} D^2}$$

Q.1

NUMERICAL BASED ON FUEL CONSUMPTION/INDICATOR DIAGRAM/POWER OUTPUT/ SLIP

SLIP

NOV 2025 AM,
AUG 2024 AM,

At 90 rev/min, a propeller of 5m pitch has an apparent slip of 15% and wake fraction of 0.10. Calculate the real slip.

Soln:-

$$\text{Given:- Pitch (P)} = 5\text{m}$$

$$\text{RPM (N)} = 90\text{ rev/min}$$

$$\text{Apparent Slip} = 15\%$$

$$\text{Wake fraction (W)} = 0.10$$

$$\text{Real slip} = \frac{V_T - V_a}{V_T} \times 100\%$$

① To find V_T (theoretical speed)

$$V_T = \frac{P \times N \times 60}{1852} \text{ Kts}$$

$$V_T = \frac{5 \times 90 \times 60}{1852}$$

$$V_T = 14.579 \text{ Kts}$$

② To find V_a (speed of advance)

$$\text{Apparent slip} = \frac{V_T - V}{V_T} \times 100\%$$

$$15\% = \frac{14.579 - V}{14.579}$$

$$0.15 = \frac{14.579 - V}{14.579}$$

$$2.189 = 14.579 - V$$

$$V = 14.579 - 2.189$$

$$V = 12.392 \text{ Kts.}$$

3/2/11 _/_/_

$$\text{Wake fraction (w)} = \frac{V - V_a}{V}$$

$$0.10 = \frac{12.392 - V_a}{12.392}$$

$$1.239 = 12.392 - V_a$$

$$V_a = 12.392 - 1.239$$

$$V_a = 11.153 \text{ Kts}$$

(iii)

$$\text{Real slip} = \frac{V_T - V_a}{V_T} \times 100\%$$

$$= \frac{14.579 - 11.153}{14.579} \times 100\%$$

$$= \frac{3.426}{14.579} \times 100$$

$$= 23.5\% \quad \underline{\underline{\text{Ans}}}$$

MAY 2025 AM
NOV 2022,
NOV 2015

The pitch angle of a propeller blade measured at radii of 1, 1.5, 2, 2.5 & 3 meters are respectively 42, 32, 26, 22 and 19 degrees.

Similar question:
JAN 2021

This propeller turns at 105 rpm and drives the ship at 22 knots. Calculate:

a) Pitch of propeller

b) Apparent slip

What are interpretations of the result?

Soln:-

a) Pitch of the propeller

$$\text{Pitch}(P) = 2\pi r \tan \theta$$

$$\text{At 1m radius : } 2\pi \times 1 \times \tan 42^\circ = 5.657 \text{ m}$$

$$\text{At 1.5m radius : } 2\pi \times 1.5 \times \tan 32^\circ = 5.889 \text{ m}$$

$$\text{At 2m radius : } 2\pi \times 2 \times \tan 26^\circ = 6.129 \text{ m}$$

$$\text{At 2.5m radius : } 2\pi \times 2.5 \times \tan 22^\circ = 6.346 \text{ m}$$

$$\text{At 3m radius : } 2\pi \times 3 \times \tan 19^\circ = 6.490 \text{ m}$$

Pitch of the propeller = Mean value

$$= \frac{5.657 + 5.889 + 6.129 + 6.346 + 6.490}{5}$$

$$= 6.102 \text{ m}$$

b) Apparent slip

$$\text{Theoretical speed, } V_T = \frac{P \times N \times 60}{1852} = \frac{6.102 \times 105 \times 60}{1852} = 20.758 \text{ m}$$

$$\text{Apparent slip} = \frac{V_T - V}{V_T} \times 100\%$$

$$= \frac{20.758 - 22}{20.758} \times 100\%$$

$$= -5.98\%$$

Interpretation:

i) Negative slip: The negative apparent slip indicates that the actual speed of the ship is greater than the theoretical speed. This typically occurs when the ship travels in following current.

ii) variable pitch: The pitch increases from the root to the tip (5.657 to 6.490m) which is a common design feature used to optimize efficiency.

FEB 2024

This pitch angles of a propeller blade measured at radii of 1, 1.5, 2, 2.5 and 3 meters are respectively 40° , 30° , 26° , 22° and 19° . Calculate:

PAPER 1

- i) the pitch of the propeller. This propeller turns at 100 rpm and drives the ship at 16 knots. If the wake fraction is 0.30. calculate ii) apparent slip
iii) the real slip

Soln:-

i) Pitch of the propeller

$$\text{Pitch}(P) = 2\pi r \tan \theta$$

$$\text{At 1m radius: } 2\pi \times 1 \times \tan 40^\circ = 5.272 \text{ m}$$

$$\text{At 1.5m radius: } 2\pi \times 1.5 \times \tan 30^\circ = 5.441 \text{ m}$$

$$\text{At 2m radius: } 2\pi \times 2 \times \tan 26^\circ = 6.129 \text{ m}$$

$$\text{At 2.5m radius: } 2\pi \times 2.5 \times \tan 22^\circ = 6.346 \text{ m}$$

$$\text{At 3m radius: } 2\pi \times 3 \times \tan 19^\circ = 6.490 \text{ m}$$

Pitch of the propeller = Mean value

$$= \frac{5.272 + 5.441 + 6.129 + 6.346 + 6.490}{5}$$

$$= 5.936 \text{ m}$$

ii) Apparent slip

$$\text{Theoretical speed, } V_T = \frac{P \times N \times 60}{1852} = \frac{5.936 \times 100 \times 60}{1852} = 19.231 \text{ kts.}$$

$$\text{Apparent slip} = \frac{V_T - V_{\text{actual}}}{V_T} \times 100\% = \frac{19.231 - 16}{19.231} \times 100\% = 16.80\%$$

iii) Real slip

$$\text{Wave fraction, } W = \frac{V - V_a}{V} \Rightarrow 0.30 = \frac{16 - V_a}{16}$$

$$4.8 = 16 - V_a$$

$$V_a = 16 - 4.8$$

$$V_a = 11.2 \text{ m}$$

$$\text{Real slip} = \frac{V_T - V_a}{V_T} \times 100\% = \frac{19.231 - 11.2}{19.231} \times 100\%$$

$$= 41.76\%$$

FEB 2025 PM,
APRIL 2021,
NOV 2013

A ship's propeller has a pitch of 6.0 meters. When running at 90 rpm, the ship's speed is 15.5 knots and speed of advance is 14.5 knots. If propeller efficiency is 70% and delivered power is 9000 kW. Calculate :

- a) Real slip b) Wake fraction c) Thrust power d) Apparent slip.

Soln:-

Given: Pitch of the propeller (P) : 6.0 m

RPM (N) : 90

Ship's speed (V) : 15.5 Kts

Speed of advance (Va) : 14.5 Kts

Propeller efficiency : 70%

Delivered power (dp) : 9000 kW

a) Real slip $\left(\frac{V_T - V_a}{V_T} \times 100\% \right)$

Theoretical speed $V_T = \frac{P \times N \times 60}{1852}$

$= \frac{6 \times 90 \times 60}{1852}$

$= 17.495 \text{ Kts}$

Real slip $= \frac{V_T - V_a}{V_T} \times 100$

$= \frac{17.495 - 14.5}{17.495} \times 100$

$= 17.119\% \text{ Ans}$

b) Wake fraction

$W = \frac{V - V_a}{V} \Rightarrow \frac{15.5 - 14.5}{15.5} \Rightarrow 0.064 \text{ Ans}$

c) Thrust power

$t_p = d_p \times \text{propeller efficiency}$

$= 9000 \times 70\%$

$= 6300 \text{ kW} \text{ Ans}$

d) Apparent slip : $\frac{V_T - V}{V_T} \times 100$

$= \frac{17.495 - 15.5}{17.495} \times 100$

$= 11.40\% \text{ Ans}$



NOV 2024 PM
OCT 2022, MAY 2018
AUG 2012

Propeller has pitch of 5.5 mtr. When running at 80 RPM, the ship speed is 13.2 knots, speed of advance is 11.0 knots, propeller efficiency of 70% and delivered power is 300 kW. Calculate:

- a) Real slip b) Wake fraction c) Thrust power d) Thrust

Soln :-

Given: Pitch of the propeller (P) : 5.5 m

RPM (N) : 80

Ship's speed (V) : 13.2 Kts.

Speed of advance (V_a) : 11.0 Kts.

Propeller efficiency : 70%.

Delivered power (d_p) : 300 kW

a) Real slip ($\frac{V_T - V_a}{V_T} \times 100\%$)

$$\text{Theoretical speed } V_T = \frac{P \times N \times 60}{1852}$$

$$\Rightarrow \frac{5.5 \times 80 \times 60}{1852} = 14.255 \text{ Kts.}$$

$$\text{Real slip} = \frac{V_T - V_a}{V_T} \times 100$$

$$\Rightarrow \frac{14.255 - 11}{14.255} \times 100 = 22.83\% \quad \text{Ans}$$

$$\text{b) Wake fraction, } W = \frac{V - V_a}{V} \Rightarrow \frac{13.2 - 11.0}{13.2} = 0.167 \quad \text{Ans}$$

c) Thrust power

$$t_p = d_p \times \text{propeller efficiency}$$

$$= 300 \times 70\%$$

$$= 210 \text{ kW} \quad \text{Ans}$$

d) Thrust

$$\text{Thrust} = \frac{\text{Thrust power}}{V_a \text{ (m/sec)}}$$

$$= \frac{210}{11 \times \frac{1852}{3600}}$$

$$= 37.110 \text{ kN} \quad \text{Ans}$$

AUG 2024 PM,
JAN 2023, NOV 2024

A propeller rotates at 2 rev/sec with a speed of advance of 12 knots & a real slip of 0.30. The torque absorbed by the propeller is 250 KN-m and the thrust delivered is 300 KN. Calculate

a) the pitch of the propeller b) the thrust power c) the delivered power.

Soln:-

$$\text{Given: RPM (N) : } 2 \text{ rev/sec} \times 60 = 120$$

$$\text{Speed of advance (V}_a\text{) : } 12 \text{ Kts.}$$

$$\text{Real slip : } 0.30.$$

$$\text{Torque absorbed : } 250 \text{ KN-m}$$

$$\text{Thrust delivered : } 300 \text{ KN}$$

a) Pitch of the propeller.

$$\text{Real slip} = \frac{V_T - V_a}{V_T}$$

$$0.30 = \frac{V_T - 12}{V_T}$$

$$0.30 V_T = V_T - 12$$

$$12 = V_T - 0.30 V_T$$

$$12 = 0.70 V_T$$

$$V_T = 17.14 \text{ Kts.}$$

$$V_T = \frac{P \times N \times 60}{1852}$$

$$17.14 = \frac{P \times 120 \times 60}{1852}$$

$$31743.28 = P \times 120 \times 60$$

$$P = 4.4 \text{ mtrs} \text{ Ans}$$

b) Thrust power

$$\text{Thrust power} = \text{Thrust} \times V_a \text{ (m/sec)}$$

$$= 300 \times \left(12 \times \frac{1852}{3600} \right)$$

$$= 1852 \text{ KW}$$

c) Delivered power

$$dp = \text{torque} \times 2\pi n$$

$$= 250 \times 2\pi(2)$$

$$= 250 \times 12.566$$

$$= 3141.5 \text{ KW}$$



FEB 2024 PAPER 2

FEB 2015

A propeller 6m diameter has a pitch ratio of 0.9, Blade area ratio of 0.48 and when running at 110 rpm has a real slip of 25% and wake fraction of 0.30. If the propeller delivered thrust of 300 kN and propeller efficiency is 65%. Calculate:

(a) Blade area (b) Ship's speed (c) Thrust power (d) Shaft power (e) Torque

Soln:-

Given: Propeller diameter (D): 6m

Pitch ratio (P) : 0.9

Blade area ratio (BAR) : 0.48

RPM (N) : 110

Real slip : 25%

Wake fraction : 0.30

Thrust delivered : 300 kN

Propeller efficiency : 65%

a) Blade area

$$\text{Blade area ratio (BAR)} = \frac{\text{Blade area}}{\pi r^2}$$

$$\text{Blade area} = \text{BAR} \times \pi r^2$$

$$= 0.48 \times \pi \times \left(\frac{6}{2}\right)^2$$

$$= 0.48 \times \pi \times 3^2$$

$$= 13.572 \text{ m}^2 \quad \underline{\text{Ans}}$$

b) Ship's speed

$$\text{Pitch ratio (P)} = \frac{\text{Pitch (P)}}{\text{Diameter (D)}}$$

$$0.9 = \frac{P}{6}$$

$$\text{Pitch of the propeller, } P = 5.4 \text{ m}$$

$$\text{Theoretical speed, } V_T = \frac{P \times N \times 60}{1852}$$

$$= \frac{5.4 \times 110 \times 60}{1852}$$

$$= 19.244 \text{ knots}$$

$$\text{Real slip} = \frac{V_T - V_a}{V_T}$$

$$0.25 = \frac{19.244 - V_a}{19.244}$$

$$4.811 = 19.244 - V_a$$

$$V_a = 14.433 \text{ Kts}$$

$$\text{wake fraction (W)} = \frac{V - V_a}{V}$$

$$0.30 = \frac{V - 14.433}{V}$$

$$0.30V = V - 14.433$$

$$14.433 = V - 0.30V$$

$$14.433 = 0.70V$$

$$V = 20.619 \text{ Kts} = \text{Ans}$$

c) Thrust power

$$\begin{aligned} \text{Thrust power} &= \text{Thrust} \times V_a (\text{m/sec}) \\ (tp) &= 300 \times \left(14.433 \times \frac{1852}{60 \times 60} \right) \\ &= 300 \times 7.425 \\ &= 2227.5 \text{ KW} = \text{Ans} \end{aligned}$$

d) Shaft power

If dp is not given, $dp = Sp$

$tp = dp \times \text{propeller efficiency}$

$$2227.5 = dp \times 65\%$$

$$dp = 3426.9 \text{ KW}$$

$$\text{i.e. } Sp = 3426.9 \text{ KW} = \text{Ans}$$

e) Torque

$$dp = \text{torque} \times 2\pi n$$

$$\text{Torque} = \frac{dp}{2\pi n}$$

$$= \frac{3426.9}{2\pi \left(\frac{110}{60} \right)}$$

$$= 297.5 \text{ N-m} = \text{Ans}$$

NOV 2023

A propeller of 5.5 diameter has pitch ratio of 0.8 when turning 120RPM, the wake fraction is found to be 0.32 and real slip 37%. Calculate the ship speed, speed of advance and apparent slip

Soln:-

Given: Propeller diameter (D) : 5.5m

Pitch ratio (p) : 0.8

RPM (N) : 120

Wake fraction (w) : 0.32

Real slip : 37%.

$$\text{Pitch ratio (p)} = \frac{\text{Pitch (P)}}{\text{Diameter (D)}}$$

$$0.8 = \frac{P}{5.5}$$

Pitch of the propeller, P = 4.4m

$$\text{Theoretical speed, } V_T = \frac{P \times N \times 60}{1852}$$

$$= \frac{4.4 \times 120 \times 60}{1852}$$

$$= 17.106 \text{ Kts}$$

a) speed of advance

$$\text{Real slip} = \frac{V_T - V_a}{V_T}$$

$$0.37 = \frac{17.106 - V_a}{17.106}$$

$$6.329 = 17.106 - V_a$$

$$V_a = 10.777 \text{ Kts} = \text{Ans}$$

b) Ship's speed

$$\text{Wake fraction (w)} = \frac{V - V_a}{V}$$

$$0.32 = \frac{V - 10.777}{V}$$

$$0.32V = V - 10.777$$

$$10.777 = V - 0.32V$$

$$10.777 = 0.68V$$

$$V = 15.849 \text{ Kts} = \text{Ans}$$

$$\begin{aligned} \text{c) Apparent slip} &= \frac{V_T - V}{V_T} \times 100 \\ &= \frac{17.106 - 15.849}{17.106} \times 100 \end{aligned}$$

MAY 2019

A propeller has diameter of 6m, pitch ratio 1.12 and works at apparent slip of 7%. For ship's speed of 15 knots, determine the RPM of the engine

Soln:-

Given : Propeller diameter (D) : 6.0m

Pitch ratio (P) : 1.12

Apparent slip : 7%

Ship's speed (V) : 15 Kts

$$\text{Pitch ratio}(P) = \frac{\text{Pitch}(P)}{\text{Diameter}(D)}$$

$$1.12 = \frac{P}{6.0}$$

Pitch of the propeller, P = 6.72m

$$\text{Apparent slip} = \frac{V_T - V}{V_T}$$

$$0.07 = \frac{V_T - 15}{V_T}$$

$$0.07V_T = V_T - 15$$

$$15 = V_T - 0.07V_T$$

$$15 = 0.93V_T$$

$$V_T = 16.129 \text{ Kts}$$

$$\text{Theoretical speed, } V_T = \frac{P \times N \times 60}{1852}$$

$$16.129 = \frac{6.72 \times N \times 60}{1852}$$

$$29870.908 = 6.72 \times N \times 60$$

$$\text{RPM, } N = 74 \text{ Rpm} \text{ } \neq \text{Ans}$$

b) If the wake fraction is 0.373. Find the real slip

$$\text{Wake fraction}(w) = \frac{V - V_a}{V}$$

$$0.373 = \frac{15 - V_a}{15}$$

$$5.595 = 15 - V_a$$

$$V_a = 9.405 \text{ Kts}$$

$$\text{Real slip} = \frac{V_T - V_a}{V_T} \times 100\%$$

$$= \frac{16.129 - 9.405}{16.129} \times 100\%$$

$$= 41.69\% \text{ } \neq \text{Ans}$$

MAY 2017

The pitch of the ship's propeller is 6m. At 105 rpm, the apparent slip is 10%. and the real slip is 24%. Calculate ship speed and wake fraction

Soln:-

Given : Pitch of the propeller (P) : 6m

RPM (N) : 105 rpm

Apparent slip : 10%

Real slip : 24%

$$\text{Theoretical speed, } V_T = \frac{P \times N \times 60}{1852}$$

$$= \frac{6 \times 105 \times 60}{1852}$$

$$= 20.410 \text{ Kts}$$

a) ship's speed $\text{Apparent slip} = \frac{V_T - V}{V_T}$

$$0.1 = \frac{20.410 - V}{20.410}$$

$$2.041 = 20.410 - V$$

$$V = 18.369 \text{ Kts} = \text{Ans}$$

b) wake fraction

$$\text{Real slip} = \frac{V_T - V_a}{V_T}$$

$$0.24 = \frac{20.410 - V_a}{20.410}$$

$$4.898 = 20.410 - V_a$$

$$V_a = 15.512 \text{ Kts}$$

$$\text{Wake fraction (w)} = \frac{V - V_a}{V}$$

$$= \frac{18.369 - 15.512}{18.369}$$

$$= 0.156 = \text{Ans}$$

AUG 2021

A ship of 12100 t displacement is 120 m long, 17.5 m beam and floats at a draft of 7.5 m in SW. The propeller has a face pitch ratio of 0.75 and when coming at 100 rpm produces ship speed of 12 knots with a real slip of 30%. Calculate the apparent slip, pitch and diameter of the propeller. The wake fraction (w) may be found from the fraction $W = 0.5 C_b - 0.05$

SOLⁿ:-Given:- pitch ratio (b) : 0.75RPM (N) : 100

Real slip : 30%

Ship speed (V) : 12 Kts.Wake fraction (w) : $0.5 C_b - 0.05$

$$= 0.5 \left(\frac{12100}{120 \times 17.5 \times 7.5 \times 1.025} \right) - 0.05$$

$$= 0.5(0.75) - 0.05$$

$$= 0.375 - 0.05$$

$$= 0.325$$

$$\text{Wake fraction}(w) = \frac{V - V_a}{V}$$

$$0.325 = \frac{12 - V_a}{12}$$

$$3.897 = 12 - V_a$$

$$V_a = 8.103 \text{ Kts}$$

$$\text{Real slip} = \frac{V_T - V_a}{V_T}$$

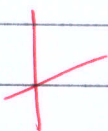
$$0.3 = \frac{V_T - 8.103}{V_T}$$

$$0.3V_T = V_T - 8.103$$

$$8.103 = V_T - 0.3V_T$$

$$8.103 = 0.7V_T$$

$$V_T = 11.576 \text{ Kts}$$



(19)

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$$\text{Theoretical speed } V_T = \frac{P \times N \times 60}{1852}$$

$$11.576 = \frac{P \times 100 \times 60}{1852}$$

$$21437.968 = P \times 100 \times 60$$

$$P = 3.57 \text{ m} = \text{Ans}$$

$$\text{Pitch ratio}(p) = \frac{\text{Pitch}(P)}{\text{Diameter}(D)}$$

$$0.75 = \frac{3.57}{D}$$

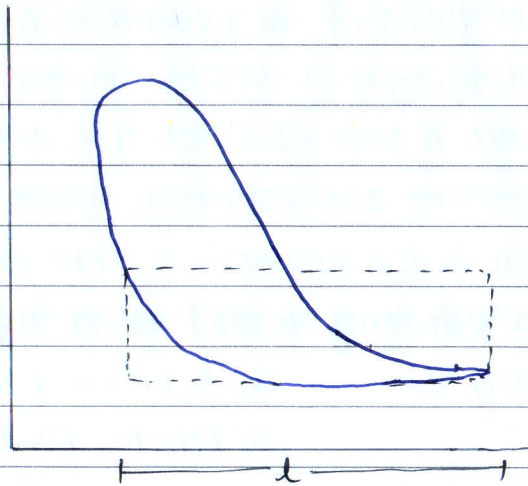
$$D = 4.76 \text{ m} = \text{Ans}$$

$$\text{Apparent slip} = \frac{V_T - V}{V_T}$$

$$= \frac{11.576 - 12}{11.576} \times 100$$

$$= -3.7\% = \text{Ans}$$

INDICATOR DIAGRAM



Area of indicator diagram = a

Average height of diagram = $\frac{a}{L}$

Average or mean indicated pressure (P_m) = $\frac{a}{L} \times K$ bar

where 'K' is spring constant bar/mm

- Work done in one cycle = Mean indicated pressure $\times$ Area of piston $\times$ Length of stroke
 $= P_m \times A \times L$
- Power is the rate of doing work
 i.e. multiply work done by number of power stroke per second.
- In a 2-stroke engine, there is 1 power stroke in every revolution.
 In a 4-stroke engine, there is 1 power stroke in every 02 revolution.
- For 2-stroke engine, $N = \text{Engine rev. per sec.}$
 For 4-stroke engine, $N = \frac{\text{Engine rev. per sec.}}{2}$

$$\text{Indicated power (ip)} = P_m \times A \times L \times N$$

where, P_m is in N/m^2

A is in m^2

L is in m

N is in power stroke per sec

FEB 2023
FEB 2016

The area of indicator diagram taken of one cylinder of a six cylinder, four stroke internal combustion engine is 378 sq. mm, the length is 70 mm and the indicator spring scale is 1 mm = 1.5 bar. The diameter of the cylinder is 205 mm, stroke 300 mm and rotational speed 360 revolution per minute. If frictional loss in the engine is 2.5 kW and transmission efficiency is 95%, propeller efficiency is 97% and hull efficiency is 98%, find the

a) Indicated power of the engines b) Delivered power
c) Thrust power d) Effective power.

State any assumption taken in your calculation.

Soln:-

Given: Engine = 4-stroke engine.

Area of indicator diagram (a) = 378 mm²

Length of diagram (L) = 70 mm

Indicator spring scale (K) = 1 mm = 1.5 bar.

Diameter of the cylinder (D) = 205 mm = 0.205 m

Stroke length (L) = 300 mm = 0.30 m

Rotational speed = 360 rev/min

Frictional loss = 2.5 kW

Transmission efficiency = 95%

Propeller efficiency = 97%

Hull efficiency = 98%

No. of cylinder = 06

a) Indicated power of the engines.

$$i_p = P_m \times A \times L \times N$$

$$\text{Mean indicated pressure, } P_m = \frac{a}{L} \times K$$

$$P_m = \frac{378}{70} \times 1.5$$

$$P_m = 8.1 \text{ bar}$$

$$P_m = 8.1 \times 10^5 \text{ N/m}^2$$

$$\text{Area of cylinder (A)} = \pi r^2$$

$$= \pi (d/2)^2$$

$$= \frac{\pi d^2}{4}$$

$$4$$

$$= \frac{\pi \times (0.205)^2}{4} = 0.033 \text{ m}^2$$

$$\text{Stroke length (L)} = 0.30 \text{ m}$$

$$\text{No. of power stroke per sec (N)} = \frac{360/60}{2} = 3$$

$$\begin{aligned} \text{Hence, indicated power (ip) per cylinder} &= 8.1 \times 0.033 \times 0.30 \times 3 \times 10^5 \text{ watt} \\ &= 24057 \text{ watt} \\ &= 24.057 \text{ kW} \end{aligned}$$

Remarks: Total indicated power of the engine will be calculated by assuming all cylinders develop similar indicator diagram and hence same power.

$$\begin{aligned} \text{Total indicated power of the engine} &= \text{ip per cylinder} \times \text{No. of cylinder} \\ &= 24.057 \times 6 \\ &= 144.342 \text{ kW} \text{ Ans} \end{aligned}$$

b) Delivered power

$$\begin{aligned} \text{Shaft power (Sp)} &= \text{ip} - \text{frictional loss} \\ &= 144.342 - 2.5 \\ &= 141.842 \text{ kW} \end{aligned}$$

$$\begin{aligned} \text{Delivered power (dp)} &= \text{Sp} \times \text{transmission efficiency} \\ &= 141.842 \times 0.95 \\ &= 134.75 \text{ kW} \end{aligned}$$

c) Thrust power

$$\begin{aligned} \text{Thrust power (tp)} &= \text{dp} \times \text{propeller efficiency} \\ &= 134.75 \times 0.97 \\ &= 130.708 \text{ kW} \end{aligned}$$

d) Effective power

$$\begin{aligned} \text{Effective power (ep)} &= \text{tp} \times \text{hull efficiency} \\ &= 130.708 \times 0.98 \\ &= 128.093 \text{ kW} \end{aligned}$$

JULY 2022
MAY 2013

The area of an indicator diagram taken of one cylinder of a 4 cylinder, four stroke engine is 378 sq. mm and length is 70 mm. Indicator spring scale is 1 mm = 100 kN/sqm. Diameter of cylinder is 250 mm, stroke of cylinder 310 mm and rotational speed 6 revs per second. Calculate indicated power of engine.

Solⁿ:-

Given: Engine/No. of cylinder: 4-stroke engine/4

Area of indicator diagram (a) = 378 mm²

Length of diagram (L) = 70 mm

Indicator spring scale (K) = 1 mm = 100 kN/m²

Diameter of the cylinder (D) = 250 mm = 0.25 m

Stroke length (L) = 310 mm = 0.31 m

Rotational speed = 6 rev per second.

Indicated power, $i_p = P_m \times A \times L \times N$

Mean indicated pressure, $P_m = \frac{a}{L} \times K$

$$= \frac{378}{70} \times 100$$

$$= 540 \text{ kN/m}^2$$

Area of cylinder (A) = $\frac{\pi d^2}{4}$

$$= \frac{\pi \times (0.25)^2}{4} = 0.049 \text{ m}^2$$

Stroke length (L) = 0.31 m

No of power stroke per sec (N) = For 4-stroke engine, $\frac{\text{Rotational speed}}{2}$

$$\Rightarrow \frac{6}{2} = 3$$

Hence, indicated power per cylinder = $P_m \times A \times L \times N$

$$= 540 \times 0.049 \times 0.31 \times 3$$

$$= 24.652 \text{ kW}$$

Indicated power of engine = Indicated power per cylinder $\times$ No of cylinder

$$= 24.652 \times 4$$

$$= 98.608 \text{ kW}$$

MARCH 2022
NOV 2017

Area of indicator diagram taken off one cylinder of a six cylinders, four stroke engine was 500 mm^2 . Length of the diagram is 100 mm . The indicator spring constant is $1 \text{ mm} = 2 \text{ bar}$. The diameter of the cylinder is 300 mm , stroke is 620 mm and rotational speed is 10 rev/sec . Calculate the indicated power of the engine assuming that all cylinder develop equal power.

Soln:-

Given : Engine / No. of cylinders : 4-stroke / 6

Area of indicator diagram (a): 500 mm^2

Length of the diagram (L): 100 mm

Indicator spring constant (K): $1 \text{ mm} = 2 \text{ bar}$

Diameter of the cylinder (D): $300 \text{ mm} = 0.30 \text{ m}$

Stroke length (L): $620 \text{ mm} = 0.62 \text{ m}$

Rotational speed : 10 rev/sec

$$ip = P_m \times A \times L \times N$$

$$\text{Mean indicated pressure, } P_m = \frac{a}{L} \times K$$

$$= \frac{500}{100} \times 2$$

$$= 10 \text{ bar}$$

$$= 10 \times 10^5 \text{ N/m}^2$$

$$\text{Area of cylinder (A)} = \frac{\pi d^2}{4}$$

$$= \frac{\pi \times (0.30)^2}{4} = 0.071 \text{ m}^2$$

$$\text{Stroke length (L)} = 0.62 \text{ m}$$

$$\text{No. of power stroke per sec (N)} = \frac{\text{For 4-stroke engine, Rotational speed}}{2}$$

$$\Rightarrow 10/2 = 5$$

$$\text{Hence, indicated power per cylinder} = P_m \times A \times L \times N$$

$$= 10 \times 0.071 \times 0.62 \times 5 \times 10^5$$

$$= 220100 \text{ watt}$$

$$= 220.1 \text{ kW}$$

$$\text{Indicated power of engine} = ip \text{ per cylinder} \times \text{No of cylinder}$$

$$= 220.1 \times 6$$

$$= 1320.6 \text{ kW} \quad \text{Ans}$$

NOV 2018

The area of indicator diagram taken on one cylinder of a 9 cylinder 2 stroke engine is 400 mm^2 , length of diagram is 65 mm . Spring scale is $1 \text{ mm} = 1.5 \text{ bar}$, cylinder diameter is 700 mm , stroke is 1650 mm . If it is running at 110 rpm . Calculate the indicated power developed. State the assumptions made. If the mechanical efficiency is 95% , the transmission losses are 4% , propeller efficiency is 95% . Determine the thrust power.

Soln:-

Given: Engine/cylinder : 2-stroke engine / 9

Area of indicator diagram (a): 400 mm^2

Length of diagram (L): 65 mm

Indicator spring scale (K): $1 \text{ mm} = 1.5 \text{ bar}$

Diameter of the cylinder (D): $700 \text{ mm} = 0.70 \text{ m}$

Stroke length (L): $1650 \text{ mm} = 1.65 \text{ m}$

RPM : 110 rpm

Mechanical efficiency : 95%

Transmission efficiency : $100 - 4 = 96\%$

Propeller efficiency : 95%

a) Indicated power

$$i_p = P_m \times A \times L \times N$$

$$\text{Mean indicated pressure (P}_m\text{)} = \frac{a}{L} \times K \text{ bar}$$

$$= \frac{400}{65} \times 1.5$$

$$= 9.231 \text{ bar}$$

$$= 9.231 \times 10^5 \text{ N/m}^2$$

$$\text{Area of cylinder (A)} = \frac{\pi D^2}{4}$$

$$= \frac{\pi (0.70)^2}{4}$$

$$= 0.385 \text{ m}^2$$

$$\text{Stroke length (L)} = 1.65 \text{ m}$$

$$\text{No. of power stroke per sec (N)} = \frac{110}{60} \quad (2\text{-stroke engine, no need to divide by 2})$$

$$= 1.833 \text{ rps}$$

$$\begin{aligned}\text{Indicated power per cylinder} &= 9.231 \times 0.385 \times 1.65 \times 1.833 \times 10^5 \\ &= 1074869.871 \text{ watt} \\ &= 1074.87 \text{ kW}\end{aligned}$$

Remarks: Total indicated power of the engine will be calculated by assuming all cylinder develop similar indicator diagram and hence same power.

$$\begin{aligned}\text{Total indicated power of the engine} &= i_p \text{ per cylinder} \times \text{no. of cylinder} \\ &= 1074.87 \times 9 \\ &= 9673.83 \text{ kW} \text{ Ans}\end{aligned}$$

b) Thrust power

$$\begin{aligned}\text{Shaft power}(s_p) &= i_p \times \text{mechanical efficiency} \\ &= 9673.83 \times 0.95 \\ &= 9190.14 \text{ kW}\end{aligned}$$

$$\begin{aligned}\text{Delivered power}(d_p) &= s_p \times \text{transmission efficiency} \\ &= 9190.14 \times 0.96 \\ &= 8822.53 \text{ kW}\end{aligned}$$

$$\begin{aligned}\text{Thrust power}(t_p) &= d_p \times \text{propeller efficiency} \\ &= 8822.53 \times 0.95 \\ &= 8381.41 \text{ kW} \text{ Ans}\end{aligned}$$

FUEL ESTIMATION

- **Admiralty coefficient:** Admiralty coefficient is a method to obtain an approximation to the power of a ship without restoring model experiment.

$$\text{Admiralty coefficient} = \frac{\Delta^{2/3} V^3}{S_p}$$

where, Δ = displacement in tonne

V = ship speed in knots.

S_p = shaft power in kW

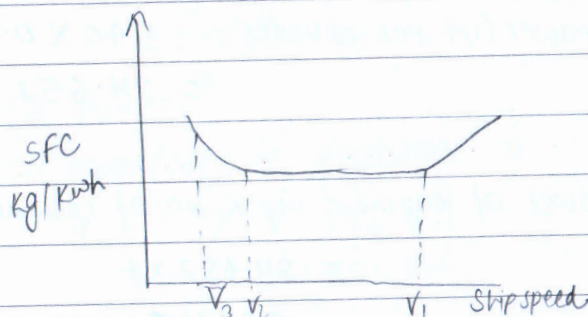
The admiralty coefficient may be regarded as constant for similar ships at their corresponding speed.

For the comparison of the engine power of similar ships, we can write

$$\frac{\Delta_1^{2/3} V_1^3}{S_{p1}} = \frac{\Delta_2^{2/3} V_2^3}{S_{p2}}$$

Normally value of Admiralty coefficient varies between 350 and 600 for different ships.

- **Specific Fuel consumption (SFC):** SFC is the quantity of fuel consumed for developing unit power in g/kwh i.e. mass of fuel consumed per hour per unit power developed in kW.



Between V_1 and V_2 , SFC may be regarded as constant.

If the ship speed varies only between these limits, then:

Fuel consumption/unit time $\propto$ power developed
 $\propto S_p$

And since, $S_p \propto \Delta^{2/3} V^3$

Fuel consumption/unit time $\propto \Delta^{2/3} V^3$

$$\text{or Fuel consumption/day} = \frac{\Delta^{2/3} v^3}{\text{Fuel coefficient}} \text{ tonne}$$

- If the displacement and fuel coefficient remain constant i.e. b/w v_1 & v_2

$$\frac{\text{Daily cons}_1}{\text{Daily cons}_2} = \left(\frac{v_1}{v_2} \right)^3$$

The values of fuel coefficients vary between 40,000 and 1,20,000.

- Total voyage consumption = Daily fuel consumption $\times$ No. of days to complete the voyage.
If D is the distance travelled at v Knots, then

$$\text{No. of days} \propto \frac{D}{v}$$

$$\text{But daily consumption} \propto v^3$$

$$\therefore \text{Total voyage consumption} \propto v^3 \times \frac{D}{v}$$

$$\propto v^2 \times D$$

$$\text{So, } \frac{\text{Voy cons}_1}{\text{Voy cons}_2} = \left(\frac{v_1}{v_2} \right)^2 \times \frac{D_1}{D_2}$$

$$\frac{\text{New voy. cons.}}{\text{Old voy. cons.}} = \left(\frac{\text{New displacement}}{\text{Old displacement}} \right)^{2/3} \times \left(\frac{\text{New speed}}{\text{Old speed}} \right)^2 \times \left(\frac{\text{New distance}}{\text{Old distance}} \right)$$

Note: All the above calculations are based on the assumptions that the ship speed lies between v_1 and v_2

- ** If the speed is reduced to v_3 , the SFC may be increased by $\alpha\%$ and daily consumption or voyage consumption will also increase by $\alpha\%$.

The effective power of ship is 1400 kW at 12 knots, the propulsive efficiency 65% and the fuel consumption 0.3 kg/kWh, based on shaft power. Calculate the fuel required to travel 10,000 nautical miles at 10 knots.

Soln:-

Given:- Effective power (e_p) = 1400 kW

V_1 = 12 knots

Propulsive efficiency = 65% = 0.65

Specific fuel consumption (SFC) = 0.3 kg/kWh

Distance to travel (D) = 10,000 NM

Speed required (V_2) = 10 knots.

$E_p = S_p \times \text{propulsive efficiency}$

$$1400 = S_p \times 0.65$$

$$S_p = 1400 / 0.65$$

$$S_p = 2153.85 \text{ kW}$$

Fuel consumption/hour at V_1 speed: $C_1 = \text{SFC} \times S_p$

$$= 0.3 \times 2153.85$$

$$= 646.154 \text{ kg/hour}$$

Fuel consumption/hour at V_2 speed: C_2

$$\frac{C_1}{C_2} = \left(\frac{V_1}{V_2} \right)^3$$

$$\frac{646.154}{C_2} = \left(\frac{12}{10} \right)^3$$

$$\frac{646.154}{C_2} = 1.728$$

$$C_2 = 373.932 \text{ kg/hour}$$

$$\text{Time to travel 10,000 NM at 10 knots} = \frac{10000}{10} = 1000 \text{ hours}$$

$$\text{So, fuel required to travel 10,000 NM at 10 knots} = C_2 \times 1000$$

$$= 373.932 \times 1000$$

$$= 373932 \text{ kg}$$

$$= 373.932 \text{ tonnes}$$

AUG 2025 PM,
AUG 2023,
AUG 2018

The daily fuel consumption of the ship at a speed of 16 knots is 48 tonnes. She has taken bunker for voyage of 1200 miles at the above speed and extra fuel for five days. She is to be proceeded to a port 1300 miles away at a speed of 15.5 knots. Calculate:

- Bunker remaining on board at the end of the voyage
- Time taken in hours to complete the above distance.

Soln:- Fuel consumption/hour at V_1 (16 knots) speed: $C_1 = \frac{48}{24} = 2$ tonnes.

Bunker taken on-board:

① Time it will take to travel 1200 miles @ 16 Kts = $\frac{1200}{16} = 75$ hrs

+

② Extra fuel for 5 days = $5 \times 24 = 120$ hrs
195 hrs

Since Bunker taken at fuel cons/hr at 16 knots speed. So fuel cons./hour at 16 Kts speed is 2 tonnes.

So, Bunker taken = $195 \times 2 = 390$ tonnes.

Let us say fuel cons./hour at V_2 (15.5 knots) speed: C_2

$$\frac{C_1}{C_2} = \left(\frac{V_1}{V_2} \right)^3$$

$$\frac{2}{C_2} = \left(\frac{16}{15.5} \right)^3$$

$$C_2 = 1.82 \text{ tonnes.}$$

Hence, fuel cons. per hour at V_2 (15.5 knots): 1.82 tonnes.

⑥ Time taken to cover 1300 miles at 15.5 knots = $\frac{1300}{15.5} = 83.9$ hours Ans

⑦ Fuel consumed: Fuel cons/hr $\times$ time taken
= 1.82×83.9
= 152.6 t

So, bunker remaining on-board at end of voyage =

Total bunker taken - bunker consumed
= $390 - 152.6$



AUG 2025 AM

FEB 2019

SIMILAR QUES:
MAY 2022

The speed of a ship is increased to 20% above normal for 8.0 hours, and then reduced to 10% below normal for 10 hours. The speed is then reduced for the remainder of the day so that the consumption for the day is the normal amount. Find the percentage difference between the distance travelled in that day and the normal distance travelled per day.

Soln:- Let us assume, ship's normal speed is 'v' knots i.e. V_1
Ship's normal fuel cons./day is x tons i.e. C_1

① ship's speed is increased to 20%.

$$\begin{aligned}\text{Now, ship's speed} &= v + 20\% \text{ of } v \\ &= v + 0.2v \\ &= 1.2v \quad \text{i.e. } V_2\end{aligned}$$

Let us say fuel cons./day at ship's speed $1.2v$ is C_2

$$\frac{C_2}{C_1} = \left(\frac{V_2}{V_1} \right)^3$$

$$\frac{C_2}{x} = \left(\frac{1.2v}{v} \right)^3$$

$$C_2 = 1.728x$$

$$\text{So, fuel cons./hr at ship's speed } 1.2v = \frac{1.728x}{24}$$

$$\begin{aligned}\text{fuel cons./hr at ship's speed } 1.2v &= \frac{1.728x}{24} \times 8 \\ &= 0.576x \text{ tons}\end{aligned}$$

② ship's speed is reduced to 10%.

$$\begin{aligned}\text{Now ship's speed} &= v - 10\% \text{ of } v \\ &= v - 0.1v \\ &= 0.9v \quad \text{i.e. } V_3\end{aligned}$$

Let us say fuel cons./day at ship's speed V_3 ($0.9v$) is C_3

$$\frac{C_3}{C_1} = \left(\frac{V_3}{V_1} \right)^3$$

$$\frac{C_3}{x} = \left(\frac{0.9v}{v} \right)^3$$

$$C_3 = 0.729x$$

$$\begin{aligned}\text{So, fuel cons./hr at ship's speed } 0.9v &= \frac{0.729x}{24} \\ \text{fuel cons. for 10hrs at ship's speed } 0.9v &= \frac{0.729x}{24} \times 10 \\ &= 0.304x \text{ tons.}\end{aligned}$$

(iii) Condition says, speed is reduced so that the consumption for the day is normal amount

Fuel cons. in 8 hrs + Fuel cons. in 10 hrs + fuel we can consume in 6 hrs = normal fuel cons.

$$\begin{aligned}0.576x + 0.304x + C_4(6\text{hr}) &= x \\ &= 0.12x\end{aligned}$$

i.e. fuel cons. for 6 hours at ship's speed $v_4 = 0.12x$

$$\text{fuel cons./hr at ship's speed } v_4 = \frac{0.12x}{6}$$

$$\begin{aligned}\text{fuel cons./day at ship's speed } v_4 &= \frac{0.12x}{6} \times 24 \\ &= 0.48x \text{ i.e. } C_4\end{aligned}$$

$$\frac{C_4}{C_1} = \left(\frac{v_4}{v_1}\right)^3$$

$$\frac{0.48x}{x} = \left(\frac{v_4}{v}\right)^3$$

$$0.48 = \left(\frac{y \cdot v}{v}\right)^3$$

$$y^3 = 0.48$$

$$y = 0.78$$

$$\text{So, } v_4 = 0.78v$$

$$\text{i.e. } v - 0.22v$$

$$\text{i.e. } v - 22\% \text{ of } v$$

That means, speed is reduced by 22% for 6 hrs to make the consumption same as the normal amount.

⇒ To find the % diff b/w distance travelled in that day & normal distance travelled per day.

$$\begin{aligned}\text{Normal distance travelled per day} &= \text{Normal speed} \times 24 \text{ hrs} \\ &= \frac{v \times 24}{24} \\ &= v\end{aligned}$$

$$\text{Distance travelled that day} \Rightarrow \text{For 8 hrs at speed } v_2 \text{ i.e. } 1.2v = 9.6v$$

$$\text{For 10 hrs at speed } v_3 \text{ i.e. } 0.9v = 9v$$

$$\text{For 6 hrs at speed } v_4 \text{ i.e. } 0.78v = 4.68v$$

$$\underline{\underline{23.28v}}$$

$$\begin{aligned} \% \text{ difference} &= \frac{23.28V - 24V}{24V} \times 100 \\ &= 3.1\% \text{ less distance travelled} \end{aligned}$$

Ans

A ship's speed is increased by 20% above normal for 8 hrs, reduced by 10% below normal for 10 hours and then is maintained at the normal value for the remainder of the day. Calculate the percentage variation in fuel consumption for that day, as compared to the daily consumption at normal speed.

Soln:- Same upto step ① & step ②

③ Condition says, speed is maintained at normal value for remainder of the day i.e. 6 hrs

So, fuel consumed will also be the normal value

i.e. fuel cons/day is x tons

fuel cons/hr is $\frac{x}{24}$ tons

fuel cons for 6 hrs is $\frac{x}{24} \times 6 = 0.25x$ tons.

So, total fuel consumed that day $\Rightarrow$

Fuel cons. for 8 hrs for speed v_2 i.e. $1.2V = 0.576x$ tons

Fuel cons. for 10 hrs for speed v_3 i.e. $0.9V = 0.304x$ tons

Fuel cons. for 6 hrs for speed v_4 i.e. $V = 0.25x$ tons

1.13x tons

Normal fuel consumption/day is x tons

$$\% \text{ diff} = \frac{1.13 - 1}{1} \times 100$$

$= 13\%$ more fuel is consumed that day

Ans

MAY 2025 PM,
NOV 2020

A ship of 18,000 tonne displacement carries 500 tonnes of fuel. If the fuel coefficient is 47250 when the ship's speed is 12 knots. Calculate:

a) The range of operation of the ship, and

b) The percentage difference in the range of the ship's operation if the speed of the ship is increased by 5%.

Soln:-

$$\text{Fuel consumption/day} = \frac{\Delta^{2/3} V^3}{\text{Fuel coefficient}}$$

$$\begin{aligned}\text{Fuel consumption/day at 12 Kts} &= \frac{18000^{2/3} \times 12^3}{47250} \\ &= \frac{689.075 \times 1728}{47250} \\ &= 25.2 \text{ tons}\end{aligned}$$

a) Range of operation of ship

$$\Rightarrow \frac{\text{Total fuel}}{\text{Fuel cons./day}} = \frac{500}{25.2} = 19.84 \text{ days} \quad \text{Ans}$$

b) ship's speed is increased by 5%.

$$\begin{aligned}\text{Now, ship's speed} &= 12 + 5\% \text{ of } 12 \\ &= 12 + 0.6 \\ &= 12.6 \text{ Kts}\end{aligned}$$

$$\begin{aligned}\text{Fuel consumption/day at 12.6 Kts} &= \frac{18000^{2/3} \times 12.6^3}{47250} \\ &= \frac{689.075 \times 2000.376}{47250} \\ &= 29.2 \text{ tons}\end{aligned}$$

$$\text{Range of operation of ship} = \frac{500}{29.2} = 17.12 \text{ days}$$

$$\% \text{ difference} = \frac{19.84 - 17.12}{19.84} \times 100$$

$$= 13.7\% \text{ decrease in range of operation} \quad \text{Ans}$$

NOV 2024 AM,
NOV 2019

The normal fuel consumption of a vessel at 15 knots is 45 tons per day. It was decided to run the vessel at a lower speed to reduce the fuel consumption to 20 tons per day. Find the speed at which the vessel should be operated to achieve the above fuel consumption. Assume that fuel consumption per unit power per hour at lower speed is 10% higher than that at 15 knots.

Soln:-

Given: Normal speed (V_1) = 15 knots.

Normal cons./day (C_1) = 45 tons

Reduced cons./day = 20 tons.

Let us assume, Reduced speed = V_2

Reduced cons./day at speed V_2 = C_2

If SFC at V_1 (15 knots) speed is F

So, SFC at V_2 speed is $F + 10\%$ of F
 $= 1.1F$

$$\frac{C_1}{C_2} = \left(\frac{V_1}{V_2} \right)^3$$

$$\frac{45}{C_2} = \left(\frac{15}{V_2} \right)^3$$

$$C_2 = 45 \times \left(\frac{V_2}{15} \right)^3$$

$$1.1 \times C_2 = 1.1 \times 45 \times \left(\frac{V_2}{15} \right)^3$$

(Reduced cons./day)

$$20 = 1.1 \times 45 \times \left(\frac{V_2}{15} \right)^3$$

$$20 = \frac{49.5 \times (V_2)^3}{3375}$$

$$(V_2)^3 = 1363.636$$

$$V_2 = 11.089 \text{ knots.}$$

Answer:-

Speed at which vessel should be operated to achieve fuel cons./day 20 tons = 11.089 Kts

Ans

MAY 2023,
AUG 2015

A vessel left port with 560 tonnes of fuel in bunkers covering a journey of 5000 nautical miles at a speed of 14 knots, arriving in port with a reserve of 80 tonnes. Calculate:

i) The speed that would have enabled the ship to arrive at her destination with the same serve of fuel if she started off from port with 510 tonnes as bunkers.

ii) Daily consumption of fuel at this new speed.

Soln:

① Fuel consumed to cover 5000 NM at 14 knots $\Rightarrow 560 - 80 = 480$ tons

Distance covered/day $\Rightarrow 14 \text{ Kts} \times 24 \text{ hrs} = 336 \text{ NM}$

Total days to cover 5000 NM $\Rightarrow 5000/336 = 14.88$ days

Fuel consumption/day at speed V_1 (14 knots): $C_1 = 480/14.88 = 32.26$ tons

② Fuel consumed to cover 5000 NM at ' x ' knots $\Rightarrow 510 - 80 = 430$ tons

Distance covered/day $\Rightarrow 'x' \text{ Kts} \times 24 \text{ hrs} = 24x \text{ NM}$

Total days to cover 5000 NM $\Rightarrow 5000/24x = \frac{208.33}{x}$

Fuel consumption/day at speed V_2 (x knots): $C_2 = \frac{430}{208.33/x}$

$$C_2 = 2.064x$$

$$\frac{C_1}{C_2} = \left(\frac{V_1}{V_2} \right)^3$$

$$\frac{32.26}{2.064x} = \left(\frac{14}{x} \right)^3$$

$$\frac{32.26}{2.064x} = \frac{2744}{x^3}$$

$$32.26x^3 = 5663.616x$$

$$x^2 = 175.562$$

$$x = 13.25 \text{ Knots} \quad \underline{\underline{\text{Ans}}}$$

ii) Daily consumption of fuel at this new speed

Fuel consumption/day at speed V_2 (13.25 knots): $C_2 = 2.064x$

$$= 2.064 \times 13.25$$

$$= 27.348 \text{ tons}$$

Ans

SEP 2022

A ship of 11500 tonne displacement travels at a speed of 14.4 knots when developing 3200kW shaft power. Calculate:

- The value of admiralty coefficient
- The percentage increase in shaft power required to increase the speed by 1.5 knots.
- The percentage increase in speed of the ship if the shaft power is increased to 3800 kW.

Soln:-

Given: Displacement (Δ) = 11,500 tons

Speed (V) = 14.4 knots

Shaft power (S_p) = 3200 kW

$$\begin{aligned}
 \text{a) Admiralty coefficient} &= \frac{\Delta^{2/3} V^3}{S_p} \\
 &= \frac{11500^{2/3} \times 14.4^3}{3200} \\
 &= \frac{511.076 \times 2985.984}{3200} \\
 &= \frac{1526064.759}{3200} \\
 &= 476.895
 \end{aligned}$$

$$\begin{aligned}
 \text{b) New speed} &= 14.4 + 1.5 \\
 &= 15.9 \text{ knots}
 \end{aligned}$$

$$\begin{aligned}
 \text{Admiralty coefficient} &= \frac{\Delta^{2/3} V^3}{S_p} \\
 476.895 &= \frac{11500^{2/3} \times 15.9^3}{S_p}
 \end{aligned}$$

$$476.895 S_p = 511.076 \times 4019.679$$

$$476.895 S_p = 2054361.465$$

$$S_p = 4307.786 \text{ kW}$$

$$\begin{aligned}
 \% \text{ increase} &= \frac{4307.786 - 3200}{3200} \times 100 \\
 &= 34.6\% \text{ increase}
 \end{aligned}$$

Ans

c) New shaft power = 3800 kW

$$\text{Admiralty coefficient} = \frac{\Delta^{2/3} V^3}{S_p}$$

$$476.895 = \frac{11500^{2/3} \times V^3}{3800}$$

$$1812201 = 511.076 \times V^3$$

$$V^3 = 3545.854$$

$$V = 15.25 \text{ Kts}$$

$$\% \text{ increase} = \frac{15.25 - 14.4}{14.4} \times 100$$

$$= 5.9\%$$

Ans



SEP 2021

NOV 2016

MAY 2014

SIMILAR QUES:
AUG 2019

Soln:-

A vessel loads bunkers for a voyage of 4500 miles at 16 knots. The main engine consumes 50 tons per day at this speed, the auxiliary plant requiring 2 tons per day. Just before sailing, the vessel is ordered to proceed on voyage at 14 knots. After 7.5 days of sailing, orders are recieved to proceed for the rest of the voyage at 16.2 knots. Calculate:

a) The time to complete the voyage.

b) The bunker remaining on arrival.

M.E Fuel consumption/day at speed V_1 (16 knots) ; $C_1 = 50$ tons

Since vessel load bunker for a voyage of 4500 miles.

$$\text{Total No. of days to complete voyage @ 16 Kts} = \frac{4500}{16} = 281.25 \text{ hour} \\ = 11.72 \text{ days.}$$

$$\text{M.E fuel consumption : } 50 \times 11.72 = 586 \text{ t}$$

$$\text{A.E fuel consumption : } 2 \times 11.72 = 23.44 \text{ t}$$

$$\text{Total bunker loaded on-board} = 609.44 \text{ t}$$

After sailing:

① For 7.5 days, vessel proceed at 14 Kts

Fuel cons./day at speed V_2 (14 Kts): C_2

$$\frac{C_1}{C_2} = \left(\frac{V_1}{V_2} \right)^3$$

$$\frac{50}{C_2} = \left(\frac{16}{14} \right)^3$$

$$50/C_2 = 1.493$$

$$C_2 = 33.5 \text{ t} + 2 \text{ t (A.E)}$$

$$= 35.5 \text{ t}$$

Total fuel consumed while proceeding at 14 Kts for 7.5 days

$$= 35.5 \times 7.5$$

$$= 266.25 \text{ t}$$

Total distance sailed while proceeding at 14 Kts for 7.5 days

$$= 14 \times (7.5 \times 24)$$

$$= 2520 \text{ NM}$$

② Rest of the voyage, proceed at 16.2 knots

$$\text{Distance to go} = 4500 - 2520$$

$$= 1980 \text{ NM}$$

No. of days required to complete the voyage @ 16.2 kts = $1980/16.2$
 $= 122.2 \text{ hrs}$
 $= 5.09 \text{ days}$

$$\frac{C_1}{C_3} = \left(\frac{V_1}{V_3} \right)^3$$

$$\frac{50}{C_3} = \left(\frac{16}{16.2} \right)^3$$

$$50/C_3 = 0.963$$

$$C_3 = 51.9t + 2t \text{ (AE)}$$

$$= 53.9t$$

Total fuel consumed while proceeding at 16.2 kts for 5.09 days
 $= 53.9 \times 5.09$
 $= 274.35t$

a) The time to complete the voyage

$$7.5 + 5.09$$

$$= 12.59 \text{ days} \text{ Ans}$$

b) The bunker remaining on arrival

Total bunker taken on-board - (Fuel cons. at 14 kts for 7.5 days + Fuel consumed at 16 kts for 5.09 days)

$$= 609.44 - (266.25 + 274.35)$$

$$= 609.44 - 540.6$$

$$= 68.84t \text{ Ans}$$