Question 1

a) In ship propulsion analysis we introduce the terms wake fraction and thrust deduction. Define briefly what is meant by these two terms:

i. Thrust deduction.

ii. Wake fraction. [Marks 4]

Question 1:

1

i) Thrust deduction: Let's consider a case where a ship is towed without installed propeller, while the water flows around the hull of the ship, a certain pressure field is set up. That is dependent to the hull form.
If the same ship was fitted with a propeller & was propelled at the same speed the pressure field around the hull would be different due to the effect of the propeller. The use of the propeller increases the speed of the flow over the hull surface, and so ~~[illegible]~~. The effect of resistance of the ship is increased compared to the first case. That resistance change is expressed by the formula $T = R(1 + a_r)$, where T = Required propeller thrust, a_r = Resistance increase factor.
The same forupula can be expressed by the below: $R = T(1-t)$ in such way we consider the deduction in propeller effective thrust that is caused by the change around the hull. In that formula t = the thrust deduction factor which represents the thrust deduction.

Evidence of answer correctness:

https://www.sciencedirect.com/topics/engineering/thrust-deduction-factor

J.S. Carlton FREng, in Marine Propellers and Propulsion (Fourth Edition), 2019

12.1.4.2 Thrust Deduction Factor

When water flows around the hull of a ship, which is being towed and does not have a propeller installed, a certain pressure field is set up, which is dependent on the hull form. If the same ship is now fitted with a propeller and is propelled at the same speed, the pressure field around the hull changes due to the action of the propeller. The propeller increases the velocities of the flow over the hull surface and hence reduces the local pressure field over the after part of the hull surface. This has the effect of increasing, or augmenting, the resistance of the vessel from that which was measured in the towed resistance case and this change can be expressed as

$$T = R(1 + a_r) \tag{12.44}$$

where T is the required propeller thrust and a_r is the resistance augmentation factor. An alternative way of expressing Eq. (12.44) is to consider the deduction in propeller effective thrust, which is caused by the change in pressure field around the hull. In this case, the relationship

$$R = T(1 - t) \tag{12.45}$$

2

ii) Wake fraction: The speed of advance of the propeller "VA" relative to the water in which it is operating is lower than the observed speed of the vessel (V). That difference in speed is the wake fraction.

Also the wake fraction coefficient is the percentage of that ship difference expressed as a percentage of the ship speed.

$$W(\text{wake fraction coefficient}) = \frac{(V - VA)}{V}.$$

The value of (W) depends on hull shape, propeller location & size.

Evidence of answer correctness:

https://www.wartsila.com/encyclopedia/term/wake-fraction-coefficient

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Wake fraction coefficient

The speed of advance of the propeller "VA" relative to the water in which it is working is lower than the observed speed of the vessel "V". This difference in speed, expressed as a percentage of the ship speed, is known as the wake fraction coefficient "w".

$w = (V-V_A)/V$

The value of the wake fraction coefficient depends largely on the shape of the hull, but also on the propeller location and size, and has great influence on its efficiency. For ships with one propeller, the wake fraction coefficient "w" is normally in the range of 0.20 to 0.45. Ships with a large block coefficient have a large wake fraction coefficient and the distribution of the water velocity around the propeller is very inhomogenous under such condition.

Question 2

a) State what is meant by the terms:

i. Harmonic excitation.

ii. Broadband excitation. **[4 Marks]**

Question 2:

3

ii) Broadband excitation, was developed by Bosschers & it was a semi-empirical method to estimate the broadband pressure fluctuations and underwater radiated noise of cavitating tip vortices.
The base of this approach was found in the method of Raestad ~~where~~ who developed an estimation procedure for the inboard noise of a cavitating tip vortex.
Raestad's method basis procedure was to relate the noise which was developed, to the size of the vortex cavity which was calculated from a potential flow code.

i) Harmonic excitation: ~~It can~~ When a system is subjected to forced harmonic excitation, it vibrates at the same frequency as that of the excitation. If the excitation frequency coincides with the natural frequency of the system, large amplitudes may result & dampers & absorbers are often used to prevent dangerous conditions.

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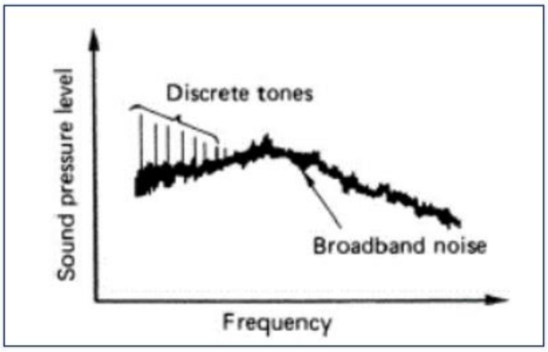
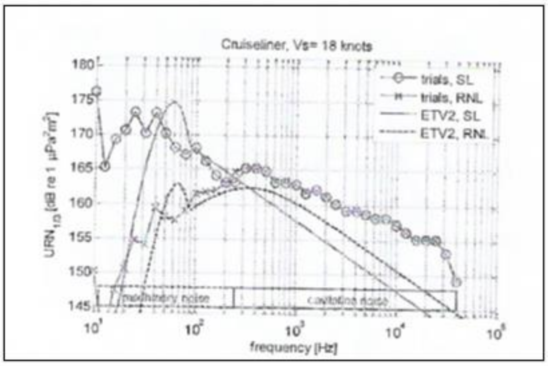
Broadband excitation

Bosschers developed a semi-empirical method to estimate the broadband pressure fluctuations and underwater radiated noise of cavitating tip vortices.

The underlying basis of his approach is to be found in the earlier method of Raestad where he developed an estimation procedure for the inboard noise of a cavitating tip vortex.

The basis of that earlier procedure was to relate the noise developed to the size of the size of the vortex cavity which was calculated from a potential flow code.





Answer of harmonic excitation correctness evidence can be found here:
https://www.sciencedirect.com/topics/engineering/harmonic-excitation

When a system is subjected to forced harmonic excitation, it vibrates at the same frequency **as that of the excitation**. If the excitation frequency coincides with the natural frequency of the system, large amplitudes may result, and dampers and absorbers are often used to prevent dangerous conditions.

https://www.sciencedirect.com › topics › engineering › ha...

Harmonic Excitation - an overview | ScienceDirect Topics

b) Consider what is meant by the coupling of vibratory modes in a marine shafting system and then identify, with explanation, two sources of potential coupling.

[9 Marks]

4)

b) Coupling between modes of vibration occurs when there is a combination of vibration modes. Two sources of potential coupling are:

1) At the crankshaft, through the reaction of the gas & inertia forces of the crank pin.

2) At the propeller, through the pitch of the blades, transitioning from torsional to thrust vibration or vice versa.

c) The axial or lateral vibration can be calculated by using either classical or finite element methods.

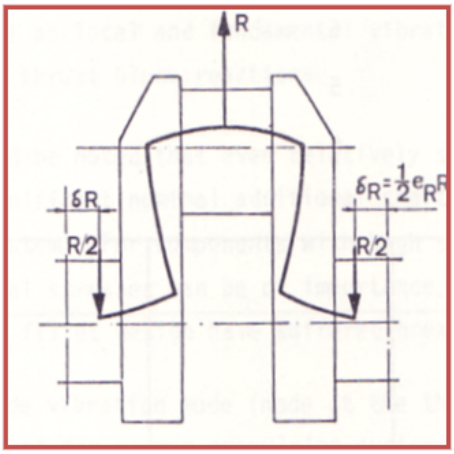
The thrust block stiffness, the propeller axial mass and damping & its seating stiffness are strongly influencing the axial vibration.

Shaft span length, bearing structural stiffness & the propeller diametral mass & inertia characteristics plus the oil film stiffness & damping are significantly influencing lateral vibration.

Coupling between modes

So far we have only thought in terms of one mode of vibration

Coupling between modes of vibration occurs in a number of ways, typically:



At the crankshaft:

- Through the reaction of the gas and inertia forces on the crank pin.

At the propeller:

- Through the pitch of the blades transitioning from torsional to thrust vibration or vice-versa.

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Axial and lateral vibration

- **Axial and lateral vibration is calculated using either classical or finite element methods.**

- **Axial vibration is strongly influenced by the thrust block stiffness, its seating stiffness and the propeller axial mass and damping.**

- **Lateral vibrations are significantly influenced by shaft span length, oil film stiffness and damping, bearing structural stiffness and the propeller diametral mass and inertia characteristics.**

Question 3

a) In relation to the subject of fatigue failure define or sketch what is meant by an S-N curve. **[4 Marks]**

9

Question 3

a) S-N curves are derived from fatigue tests, these are performed by applying a cyclic stress with constant amplitude on specimens until failure of the specimen. In some cases the test is stopped after a very large number of cycles. Those curves describe the fatigue properties of a material.

Find evidence of answer correctness here:

https://www.fatec-engineering.com/2018/02/20/description-of-a-s-n-curve/

Description of a S-N Curve

Posted on 20 February 2018 by Johannes Homan

Fatigue properties of materials are often described using the fatigue limit or the S-N curve (fatigue curve, Wöhler curve). The S-N curve describes the relation between cyclic stress amplitude and number of cycles to failure. The figure below shows a typical S-N curve. On the horizontal axis the number of cycles to failure is given on logarithmic scale. On the vertical axis (either linear or logarithmic) the stress amplitude (sometimes the maximum stress) of the cycle is given.
S-N curves are derived from fatigue tests. Tests are performed by applying a cyclic stress with constant amplitude (CA) on specimens until failure of the specimen. In some cases the test is stopped after a very large number of cycles (N>10^6). The results is then interpreted as infinite life.

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b) Discuss what is meant by the term fretting fatigue and what conditions are necessary for fretting fatigue to develop. In your answer explain why this is one of the most dangerous forms of fatigue. **[9 Marks]**

Question 3: 5

b) Fretting fatigue is a case of fatigue which occurs as a result of combined mechanical & chemical action.

In order fretting fatigue to develop, [illegible] the following conditions have to be present:

1) Points of asperity on the material which make contact.

2) The presence of a sufficiently high stress in the vicinity of the contacting points that cause surface cracking.

3) Ability of two surfaces to move relative to each other, even by a small amount.

Fretting fatigue is one of the most dangerous forms of fatigue because:

1) It can occur at very low stress levels & without warning.

2) It is difficult to analyse.

3) Parameters related to the contacting surfaces, material & global mechanical properties & environmental

Fretting fatigue

Fretting fatigue is a special case of fatigue action which results from combined mechanical and chemical action.

Typical situations in which the mechanism can occur are:

- Holes which house bolt shanks or rivets
- Contacting strands in wire ropes
- Key and keyway interfaces
- Leaf springs
- Flanges
- Splines

Fretting Fatigue

- Fundamental conditions necessary for the mechanism to develop.
  - Ability of the two surfaces to move relative to each other, albeit by a small amount
  - Points of asperity on the material which make contact
  - The presence of a sufficiently high stress in the vicinity of the contacting points to cause surface cracking

- Under these conditions, scars tend to form relatively rapidly and frequently contain an oxide deposit.

  – In Steels The oxide is reddish-brown
  – In Aluminium The oxide is black

Fretting fatigue

- It is difficult to analyse.
- It can occur at very low stress levels and without warning.
- There are thought to be some 40 to 50 potential interacting parameters involved for which few theoretical models of their behaviour exist.
- These parameters are related to the contacting surfaces, environmental conditions and to the material and global mechanical properties.
- The effect of the fretting is to significantly reduce fatigue life – typically between 1.5 and 4.

c) Explain what is meant by the term *Butterflies* when found in a material subject to cyclic stresses: Typically that of gearwheel teeth or rolling element bearing raceway.

[12 Marks]

6

conditions.

4) There are about 40 to 50 potential interacting parameters involved, for which few theoretical models of their behaviour exist.

5) The fatigue life can be significantly reduced by the effect of the fretting.

c) Butterflies generally occur at oxide or compound inclusions in the material in rolling element bearing washers. They are normally oriented at about 45° to the plane of the raceway & the cracks which they prece[de]. Within the Butterfly wing the material changes generally phase to a pearlitic structure within the surrounding matrix. Frequently cracks develop along these boundaries. The butterflies are considered to be signs of material overload & are frequently thought in terms of lower fatigue limit. Their occurence is an indication that surface stress levels have occurred in the range of 1000-3500 MPa

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Butterflies in a material

- In rolling element bearing washers butterflies generally occur at oxide or compound inclusions in the material.
- They may indicate that surface stress levels have occurred in the range 1000 MPa – 3500 MPa.
- They are normally oriented at about 45° to the plane of the raceway and the cracks which they precede.

- Within the butterfly wing the material generally changes phase to a pearlitic structure within the surrounding matrix.
- Cracks frequently develop along these boundaries.
- Butterflies are considered to be signs of material overload and are frequently thought of in terms of lower fatigue limit.

Question 4

a) Define or sketch what is meant in the context of a ship by the phrases:

i. A direct drive propulsion system.

ii. A diesel-electric propulsion system

Find this question answer in the following pages. **[4 Marks]**

b) Discuss what is meant by the term Ship System and explain why it is necessary to incorporate this concept into modern ship design.

[9 Marks]

Question 4: 7

b) Ship system is considered the level of digitisation, integration, automation & digitalisation of ship's operations. There is a trend of increase on the above with each new generation of ships which are being built.

Information technology (IT) and operational technology (OT) are being networked together & they are most of the times both, connected to the internet.

Intergration between ship's systems & connection to the internet plus incorporation of the above concepts to modern ship design is necessary as we live in a digital world & the effectiveness of ship operations should be increased by making use of the uptodate technological advancements so greater results can be achieved.

Cyber security

- The operation of ship systems tend to rely on some level of digitisation, digitalisation, integration and automation.
- This trend is increasing with each new generation of ships that are built.
- More particularly Information Technology (IT) and Operational Technology (OT) are being networked together.
- Frequently both IT and OT are connected to the internet.

Question 4

a) Define or sketch what is meant in the context of a ship by the phrases:

i. A direct drive propulsion system.

ii. A diesel-electric propulsion system

Find this question answer below. **[4 Marks]**

c) What is meant by a failure modes and effects analysis and describe how such an analysis might be conducted. **[12 Marks]**

c) failure mode & effect analysis is an identification process of the equipment or sub systems mode of operation. It includes identification of potential failure modes & their causes plus effect evaluation on the system of each failure mode. Finding measures for reducing the associated risks with each failure mode as long as trials & testing necessary to prove conclusions.

a) i) Direct drive & V-drive propulsion systems are both inboard propulsion systems, which means the engine drives a propshaft that passes through the ship's bottom & the steering is accomplished by the rudder.

ii) Electric propulsion with diesels as prime movers. Diesel electric drive takes less space than the equivalent direct two stroke engine allowing the aft section to be slimmer & giving better flow over the propeller.

Failure Modes and Effects Analysis

A Failure Modes and Effects Analysis is to:

I. Identify the equipment or sub-systems, mode of operation and the equipment.

II. Identify potential failure modes and their causes.

III. Evaluate the effects on the system of each failure mode.

IV. Identify measures for reducing the risks associated with each failure mode.

V. Identify trials and testing necessary to prove conclusions.

Find evidence of answer 4a correctness here:
https://www.discoverboating.com/resources/v-drive-vs-direct-drive

Direct Drive

A direct drive system places the engine or engines near the center of the boat. Power passes from the engine to a transmission that enables forward-neutral-reverse shifting, and then to the **propshaft**, which passes through the boat bottom at a 7- to 12-degree angle. This angle means some of the energy from the prop thrust is always lifting the boat, rather than pushing it forward.