March 2020

10. With reference to transverse stresses in a vessel's hull:

(a) state the cause of the stress when the vessel is:

(i) floating in still water; (1)

(ii) being acted on by waves; (2)

(iii) drydocked. (1)

(b) state the areas where the stress is a maximum when the vessel is:

(i) floating in still water; (1)

(ii) drydocked; (1)

(c) describe the structure that resists the stress. (4)

June 2021

June 2021

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(i) floating in still water; (1)

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(b) state the areas where the stress is a maximum when the vessel is:

(i) floating in still water; (1)

(ii) drydocked; (1)

(c) describe the structure that resists the stress. (4)

Transverse Stresses in a Ship's Hull: Causes, Locations, and Resistance

(a) Cause of Transverse Stress:

(i) Floating in Still Water:

- **Cause:** The primary cause of transverse stress in still water is the static pressure of the water acting perpendicular to the hull.
- **Explanation:** As the vessel displaces water, the water exerts an upward buoyant force on the hull bottom. This force is counteracted by the weight of the vessel acting downwards.

However, this weight distribution isn't perfectly uniform throughout the length of the vessel. Heavier machinery or cargo may be concentrated in specific areas, creating an uneven distribution of forces and leading to slight bending of the hull in a transverse direction (sideways).

(ii) Being Acted on by Waves:

- **Cause:** Waves generate dynamic forces that act on the hull, causing significant transverse stresses.
- **Explanation:** Wave action can subject the vessel to various forces, including:
  - **Wave Buoyancy:** As the wave profile passes, the hull experiences varying buoyant forces depending on its position relative to the wave crest and trough. This creates a dynamic bending moment that stresses the hull transversely.
  - **Slamming:** In rough seas, the vessel might slam against the wave crest, inducing a sudden and concentrated force that can cause high transient transverse stresses.

(iii) Drydocked:

- **Cause:** When a vessel is drydocked and supported on blocks, the water pressure that normally counteracts its weight is removed.
- **Explanation:** The hull weight is now entirely supported by the keel blocks and bilge blocks at discrete points. This concentrated support creates a significant bending moment that stresses the hull transversely, particularly between the support points.

(b) Areas of Maximum Stress:

(i) Floating in Still Water:

- **Location:** Maximum stress typically occurs at the **amidships** section (middle of the vessel's length) due to the combined effects of weight distribution and overall beam (width) of the hull.

(ii) Drydocked:

- **Location:** Maximum stress occurs at the points where the hull rests on the **support blocks**, particularly between the keel blocks and at the bilges (areas where the hull curves inward towards the bottom).

(c) Structures Resisting the Stress:

The primary structures that resist transverse stresses in a ship's hull are:

- **Double Bottom (if present):** This is a structural strengthening element involving a second inner hull bottom. It provides additional vertical strength and helps distribute loads more evenly, reducing transverse stresses.
- **Longitudinal Stiffeners:** These are vertical or horizontal beams running along the length or height of the hull. They act like internal girders, stiffening the hull and resisting bending forces.
- **Bulkheads:** These are vertical partitions dividing the hull into watertight compartments. They add rigidity to the hull and help resist transverse stresses by acting like transverse beams.
- **Deck Girders:** These are horizontal beams running across the width of the vessel within the deck structure. They help distribute loads across the deck and contribute to resisting transverse bending moments.

Overall Design: The overall design and scantling (thickness) of the hull plates also play a crucial role in resisting transverse stresses. Thicker plates and strategically placed reinforcements in high-stress areas can significantly improve the hull's strength and resistance to deformation.

June 2020

June 2020

10. (a) Define the term *sheer stress*. (3)

(b) Explain how the hull of a vessel may be subject to *sheer stress* in EACH of the following:

(i) while in a seaway; (4)

(ii) while in still water. (3)

Sheer Stress in a Ship's Hull

(a) Sheer Stress Definition:

Sheer stress is a tangential force acting parallel to the surface of a material that tends to cause the material to deform by sliding along internal planes. Imagine two layers of material trying to slide past each other in opposite directions.

(b) Sheer Stress in a Ship's Hull:

(i) Sheer Stress While in a Seaway:

- **Causes:** Wave action can subject a ship's hull to various forces that induce sheer stress:
  - **Wave Bending:** As waves pass, the hull experiences a dynamic bending moment. This bending can cause a shearing action within the hull structure, particularly at locations where the curvature changes rapidly (e.g., bow and stern sections).
  - **Slamming:** In rough seas, the hull might slam against the wave crest. This sudden impact can create a localized shearing force along the bottom plating, concentrated at the point of contact.
  - **Torsional Loads:** Waves can also induce twisting forces (torsion) on the hull, especially when encountering waves at an angle. This torsional loading creates a shearing action within the hull structure.

(ii) Sheer Stress While in Still Water:

- **Causes:** While less prominent than in a seaway, sheer stress can still occur in still water under certain circumstances:
  - **Uneven Cargo Distribution:** Uneven distribution of cargo weight within the vessel can create a twisting moment that translates to shearing forces within the hull structure.
  - **Maneuvering:** During maneuvers (turning or changing course), the rudder generates a lateral force that can induce a twisting moment and cause shearing stresses in the hull, particularly concentrated towards the stern.

Important Note:

While sheer stress can occur in still water, the dynamic nature of waves in a seaway significantly amplifies the potential for, and severity of, sheer stress within the ship's hull.

Nov 2020

Nov 2020

10. (a) Explain what is meant by the term *pounding* as applied to a vessel being driven hard in a seaway. (3)

(b) Explain how *panting* may often occur at the same time as pounding in heavy seas. (3)

(c) Describe how the hull is strengthened to resist *panting* and *pounding*. (4)

Question 10. Candidates lose marks by not stating specific hull areas for strengthening to resist panting and pounding. Most think that pounding resistance is simply by increasing scantling size.

Pounding and Panting in Ships: Causes and Mitigation Strategies

(a) Pounding:

Pounding refers to the violent impact of the vessel's forward sections (bow) against the water surface when driven hard in a head sea (waves directly ahead). This typically occurs in rough seas with large waves and high vessel speeds.

- **Mechanism:** As the vessel encounters a wave crest, the bow rises and may emerge partially out of the water. When the bow descends rapidly towards the next wave trough, it can slam against the water surface with significant force. This impact can cause localized damage to the bow plating and can also transmit shockwaves through the hull structure, potentially affecting other areas of the vessel.

(b) Panting:

Panting refers to the rapid inward and outward flexing of the forward hull plating, particularly at the bow and forepeak (compartment at the extreme forward end). This bellows-like effect is often synchronized with the wave encounter frequency.

- **Mechanism:** As the vessel rides waves, the varying water pressure distribution along the length of the hull creates a pressure differential. The bow section experiences alternating high and low pressures as it encounters wave crests and troughs. This pressure difference causes the relatively flexible plating at the bow to flex inwards (when encountering a wave trough) and outwards (when encountering a wave crest).

(c) Hull Strengthening for Pounding and Panting:

- **Forepeak Bulkhead:** A strong and well-reinforced forepeak bulkhead located at the extreme forward end of the cargo hold helps distribute impact loads from pounding more evenly throughout the hull structure.

- **Double Bottom:** A double bottom provides additional structural stiffness and strength in the bow area, helping to resist the inward flexing during panting.
- **Longitudinal Stiffeners:** Additional longitudinal stiffeners (vertical beams) running along the length of the forepeak can help to resist the inward and outward flexing of the plating during panting.
- **Increased Plate Thickness:** The bow plating itself may be increased in thickness compared to other areas of the hull to withstand the higher local stresses from pounding and wave impacts.
- **Sloped Forefoot:** A carefully designed bow shape with a sloped forefoot can help to deflect wave forces more gently and reduce slamming impacts.

Overall Design: The ship's overall design plays a crucial role in mitigating pounding and panting. Factors like hull form, deadrise angle (angle of the bottom plating with the vertical), and longitudinal strength are considered during the design phase to optimize the vessel's ability to handle rough seas while minimizing the risks of pounding and panting.

April 2021

April 2021

10. With reference to a vessel's hull:

(a) explain the meaning of EACH of the following:

(i) dynamic stress; (3)

(ii) static stress; (3)

(b) state TWO examples of EACH type of stress explained in part (a). (4)

Stresses Acting on a Ship's Hull: Dynamic vs. Static

(a) Types of Stress:

(i) Dynamic Stress:

Dynamic stress refers to a time-varying force acting on a material that causes the material to deform or vibrate. The magnitude and direction of the stress can change rapidly over time. In a ship's hull, dynamic stresses are primarily caused by the interaction with waves and the ever-changing sea environment.

(ii) Static Stress:

Static stress refers to a constant force acting on a material that tends to deform the material without any significant change over time. In a ship's hull, static stresses are caused by constant or slowly changing loads.

(b) Examples of Dynamic and Static Stress:

(i) Dynamic Stress Examples:

1. **Wave-Induced Bending:** As waves pass, the hull experiences a dynamic bending moment due to the varying buoyancy forces acting along its length. This bending creates dynamic stresses that can cause the hull to flex.
2. **Slamming:** When encountering a large wave crest, the vessel's bow might slam against the water surface. This sudden impact generates a high-intensity, short-duration dynamic stress concentrated at the point of contact.

(ii) Static Stress Examples:

1. **Cargo Weight:** The weight of the cargo acting downwards on the hull bottom creates a static stress that needs to be supported by the hull structure. The distribution of cargo weight can also influence the magnitude and location of static stresses.
2. **Self-Weight:** The weight of the vessel itself, including its machinery, equipment, and structure, acts as a constant downward force on the hull. This self-weight creates a static stress that is evenly distributed throughout the hull

June 2023

June 2023

10. With reference to longitudinal stresses in a vessel's hull:

(a) state the cause of the stress; (3)

(b) state the areas where the stress is a maximum; (3)

(c) describe the structure that resists the stress. (4)

June 2021

June 2021

9. With reference to longitudinal stresses in a vessel's hull:

(a) state the cause of the stress; (3)

(b) state the areas where the stress is a maximum; (3)

(c) describe the structure that resists the stress. (4)

March 2020

March 2020

9. With reference to longitudinal stresses in a vessel's hull:

(a) state the cause of the stress; (3)

(b) state the areas where the stress is a maximum; (3)

(c) describe the structure that resists the stress. (4)

Longitudinal Stresses in a Ship's Hull

(a) Cause of Longitudinal Stress:

Longitudinal stress in a ship's hull arises from forces acting along the length of the vessel that tend to bend or stretch the hull. These forces can be caused by a variety of factors:

- **Vertical Bending:** The primary cause is the **distribution of weight and buoyancy** along the ship's length. The weight of the vessel and its cargo acts downwards, while the hydrostatic pressure of the water exerts an upward buoyancy force. If these forces are not evenly distributed, they can create a bending moment that stresses the hull longitudinally.
- **Hogging and Sagging:** Depending on the distribution of weight and wave action, two main scenarios can occur:
    - **Hogging:** When the vessel is supported on either end by wave crests, with the center unsupported in a wave trough, the hull tends to bend upwards in the center, creating a hogging condition.
    - **Sagging:** Conversely, when the vessel is supported in the center by a wave crest and the ends are in wave troughs, the hull tends to bend downwards in the center, creating a sagging condition.

(b) Areas of Maximum Stress:

The areas where longitudinal stress is a maximum depend on the specific loading condition (hogging or sagging):

- **Hogging:** During hogging, the maximum stress typically occurs at the **amidships** section (middle of the vessel's length) on the **deck** due to the combined effects of weight concentration and upward bending moment.
- **Sagging:** During sagging, the maximum stress typically occurs at the **amidships** section on the **bottom** plating as the hull tends to sag downwards under the weight and the wave action creates a downward bending moment.

(c) Structures Resisting the Stress:

The primary structures that resist longitudinal stresses in a ship's hull are:

- **Double Bottom (if present):** This acts like a horizontal girder, adding vertical and longitudinal strength to the hull. It helps distribute loads more evenly and resists the bending moment.

- **Longitudinal Stiffeners:** These are vertical or horizontal beams running along the length or height of the hull. They act like internal girders, stiffening the hull and resisting bending forces. They are particularly crucial in areas where longitudinal stresses are concentrated.
- **Deck Girders:** These are horizontal beams running across the width of the vessel within the deck structure. They help distribute loads across the deck and contribute to resisting longitudinal bending moments, especially during hogging conditions.
- **Keel:** The keel acts as the main longitudinal stiffener at the bottom of the hull. It provides rigidity and strength against longitudinal bending forces.

Overall Design: The overall design and scantling (thickness) of the hull plates also play a significant role. Thicker plates and strategically placed reinforcements in high-stress areas can significantly improve the hull's resistance to longitudinal bending.

April 2021

April 2021

9. With reference to a vessel's hull:

(a) state the meaning of the term *racking*; (2)

(b) explain how racking occurs; (4)

(c) state the structures that resist racking. (4)

Racking in a Ship's Hull

(a) Racking Definition:

Racking refers to a distortion of the ship's hull structure caused by **transverse stresses** acting in a horizontal plane. Imagine the hull twisting slightly out of shape, like a rectangle warping into a parallelogram.

(b) How Racking Occurs:

Racking typically occurs when a vessel is subjected to forces that act perpendicular to the longitudinal axis (length) of the hull. These forces can arise from various situations:

- **Wave Action:** In rough seas, waves can exert uneven buoyant forces on different sides of the hull, particularly when encountering waves at an angle. This uneven loading can cause the hull to twist slightly, inducing racking stresses.
- **Shifting Cargo:** If cargo is not properly secured within the vessel, sudden movements or shifting of cargo can create unbalanced forces that lead to racking.
- **Grounding:** When a vessel accidentally runs aground and impacts the seabed unevenly on one side, the resulting forces can cause significant racking stresses.

(c) Structures Resisting Racking:

Several key structures within the ship's hull work together to resist racking stresses:

- **Transverse Bulkheads:** These are vertical partitions dividing the hull into watertight compartments. They act like internal walls, providing significant rigidity and resisting the forces trying to twist the hull out of shape.
- **Double Bottom (if present):** A double bottom acts like a horizontal diaphragm, adding transverse stiffness and strength to the hull. It helps distribute loads more evenly across the width of the vessel and resists racking forces.
- **Longitudinal Stiffeners:** While primarily designed for longitudinal strength, longitudinal stiffeners (vertical beams) running along the hull sides can also contribute to resisting racking to some extent by providing additional stiffness against transverse deformation.
- **Deck Girders and Web Frames:** These horizontal and vertical structures within the deck and inner hull can help distribute loads transversely and provide additional resistance to racking forces acting on the upper sections of the hull.

Overall Design: The overall design and scantling (thickness) of the hull plating also play a role. Adequate thickness of plating, particularly in areas prone to racking stresses, can improve the hull's resistance to twisting deformation.

Nov 2018

Nov 2018

10. With reference to the application of protective coatings to a vessel's hull:

    (a) state the functions that the coating should perform; (3)

    (b) state the legislation that applies to certain coatings and what certification is required to comply with it; (2)

    (c) outline the process for re-coating the hull of a vessel in drydock. (5)

Protective Coatings for Ship Hulls: Functions, Regulations, and Re-coating Process

(a) Functions of a Ship Hull Coating:

A well-applied protective coating system for a ship's hull serves several critical functions:

- **Corrosion Protection:** The primary function is to protect the hull steel from corrosion caused by seawater exposure and atmospheric conditions. The coating acts as a barrier, isolating the steel from the corrosive environment.
- **Biofouling Control (Antifouling):** Marine organisms like barnacles, algae, and mussels can attach themselves to the hull, increasing drag and reducing fuel efficiency. Antifouling coatings are designed to deter or slow down the growth of these organisms, thereby maintaining smooth hydrodynamic performance.
- **Improved Fuel Efficiency:** A smooth, clean hull coated with an antifouling paint experiences less frictional resistance from water compared to a fouled hull. This translates to improved fuel efficiency and reduced emissions.

- **Aesthetic Appearance:** Coatings provide a uniform and aesthetically pleasing appearance to the hull. They can also be used for signage and identification purposes.

(b) Legislation and Certification:

International Maritime Organization (IMO) regulations play a significant role in ship hull coatings. The key regulation is the **International Convention on the Control of Harmful Anti-Fouling Systems on Ships (AFS Convention)**. This convention aims to minimize the introduction of harmful organisms and chemicals into the marine environment through antifouling systems.

- **Compliance Requirements:** The AFS Convention regulates the use of certain biocidal compounds in antifouling coatings. Vessels may be required to use specific coating types that comply with the latest regulations.
- **Certification:** To demonstrate compliance with the AFS Convention, vessels may need to carry an **International Anti-Fouling System Certificate (IASC)**. This certificate verifies the type of antifouling coating used and ensures it meets the convention's requirements. Issuance of the IASC typically involves surveys by authorized classification societies.

(c) Re-coating Process in Drydock:

Re-coating a ship's hull in drydock involves a multi-step process to ensure a high-quality and long-lasting coating application:

1. **Preparation:** The vessel enters a drydock where the hull becomes fully accessible for inspection and work. All previous coating layers are carefully removed through mechanical abrasion (blasting or grinding) or chemical stripping. The exposed hull steel is then thoroughly cleaned and high-pressure washed to remove debris, contaminants, and salts.
2. **Surface Repair:** Any damages to the hull steel such as dents, cracks, or areas of corrosion are repaired by welding or applying epoxy fillers to ensure a smooth and sound surface for coating application.
3. **Coating Application:** Several layers of paint are applied to the prepared hull surface in a controlled environment with appropriate temperature and humidity conditions. The specific coating system used will depend on the vessel type, operating profile, and regulatory requirements. Typically, a primer coat is applied first, followed by multiple layers of antifouling paint and a topcoat for protection and aesthetics.
4. **Inspection and Quality Control:** Each coating layer is thoroughly inspected for thickness, uniformity, and absence of defects before applying the subsequent

Nov 2018 23rd

10. With reference to stresses and strain in vessels, describe, with the aid of a sketch, EACH of the following:

(a) panting; (2)

(b) pounding; (2)

(c) racking; (2)

(d) hogging; (2)

(e) sagging; (2)

Stresses and Strains in Vessels: A Breakdown of Key Terms

(a) Panting:

- **Description:** Panting refers to the rapid **inward and outward flexing** of the forward hull plating, particularly at the bow and forepeak (compartment at the extreme forward end). It resembles a bellows effect, with the flexing synchronized with the wave encounter frequency.
- **Cause:** The primary cause is the **dynamic pressure difference** acting along the length of the hull as the vessel encounters waves. The bow section experiences alternating high and low pressures as it rides over wave crests and troughs. This pressure variation causes the relatively flexible plating at the bow to flex inwards (when encountering a wave trough) and outwards (when encountering a wave crest).
- **Stress:** The rapid flexing creates **dynamic stresses** (time-varying forces) in the plating, causing it to bend and potentially fatigue over time.

(b) Pounding:

- **Description:** Pounding refers to the **violent impact** of the vessel's forward sections (bow) against the water surface when driven hard in a head sea (waves directly ahead). This typically occurs in rough seas with large waves and high vessel speeds.
- **Cause:** As the vessel encounters a wave crest, the bow rises and may emerge partially out of the water. When the bow descends rapidly towards the next wave trough, it can slam against the water surface with significant force.
- **Stress:** The impact creates a localized **high-intensity, short-duration dynamic stress** concentrated at the point of contact. This can damage the bow plating and transmit shockwaves through the hull structure, potentially affecting other areas.

(c) Racking:

- **Description:** Racking refers to a **distortion** of the ship's hull structure caused by **transverse stresses** acting in a horizontal plane. Imagine the hull twisting slightly out of shape, like a rectangle warping into a parallelogram.
- **Cause:** Racking typically occurs when a vessel is subjected to forces that act perpendicular to the longitudinal axis (length) of the hull. These forces can arise from wave action in rough seas

(uneven buoyant forces on different sides), shifting cargo within the vessel, or grounding on the seabed unevenly on one side.
- **Stress:** The twisting motion creates **transverse stresses** within the hull structure, putting strain on bulkheads, longitudinal stiffeners, and other structures designed to resist such forces.

(d) Hogging:

- **Description:** Hogging refers to a **longitudinal bending** condition in a vessel's hull where the **midsection rises** and the **ends dip down**. Imagine the vessel bending upwards in the center like an inverted U-shape.
- **Cause:** The primary cause is the **distribution of weight and buoyancy** along the ship's length. When the vessel is supported on wave crests at either end, with the center unsupported in a wave trough, the bending moment created by these forces causes hogging.
- **Stress:** Hogging induces **longitudinal stresses** in the hull. The deck experiences a **tensile stress** (pulling force) on the topside and a **compressive stress** (pushing force) on the underside in the amidships section.

(e) Sagging:

- **Description:** Sagging refers to a **longitudinal bending** condition in a vessel's hull where the **midsection dips down** and the **ends rise**. Imagine the vessel bending downwards in the center like a U-shape.
- **Cause:** Sagging occurs when the **opposite** scenario of hogging takes place. The vessel is supported in the center by a wave crest, while the ends are in wave troughs. This creates a bending moment that causes the hull to sag downwards.
- **Stress:** Sagging also induces **longitudinal stresses** in the hull. The deck experiences a **compressive stress** (pushing force) on the topside and a **tensile stress** (pulling force) on the underside in the amidships section.

May 2021 14th

May 2021 14th

10. Explain the cause and effect of vibration on a vessel. (10)

Vibration in Ships: Causes, Effects, and Concerns

Vibration is a frequent occurrence in ships, caused by various internal and external factors. While some levels of vibration are inevitable, excessive vibration can have detrimental effects on the vessel, crew, and cargo.

Causes of Vibration:

- **Machinery:** The primary source of vibration on most vessels is the operation of engines, generators, and other onboard machinery. The rotating parts of these machines can generate unbalanced forces that transmit vibrations through the hull structure.

- **Propeller Forces:** The rotation of the propeller can create fluctuating forces on the shaft and hull, leading to vibrations. These forces can vary depending on factors like propeller design, rotation speed, and interaction with the water flow.
- **Wave Action:** Waves can excite vibrations in the hull structure as the vessel encounters varying buoyancy forces along its length. The wave encounter frequency can resonate with the ship's natural frequencies, amplifying vibrations.
- **Slamming:** In rough seas, the violent impact of the bow against waves (pounding) can generate shockwaves that travel through the hull, causing short-term but intense vibrations.
- **Cargo Shifting:** Improperly secured cargo can shift or roll during voyages, creating unbalanced forces that lead to vibrations.

Effects of Vibration:

- **Structural Fatigue:** Excessive vibration can cause metal fatigue in the hull structure over time. This can lead to cracks, weakening of critical components, and potential safety hazards.
- **Noise and Discomfort:** Vibrations can transmit as noise and discomfort for crew and passengers. This can lead to fatigue, reduced efficiency, and even seasickness.
- **Equipment Damage:** Delicate onboard equipment can be damaged by excessive vibration, leading to malfunctions and costly repairs.
- **Reduced Efficiency:** Vibrations can increase resistance on moving parts within the vessel, leading to reduced overall efficiency and increased fuel consumption.

Concerns and Mitigation Strategies:

- **Safety:** Fatigue cracks caused by vibration can pose a serious safety risk if they occur in critical structural components. Regular inspections and maintenance are crucial to detect and address vibration-related issues.
- **Comfort:** Excessive vibration can significantly impact the comfort and well-being of crew and passengers. Ship designers and operators strive to minimize vibration levels through careful machinery selection, mounting techniques, and hull design to improve habitability.
- **Efficiency:** Reducing vibration not only improves comfort but also contributes to better fuel efficiency. Modern vessels often employ vibration dampening technologies like active vibration control systems to mitigate these issues.

Overall, understanding the causes and effects of vibration is crucial for ensuring the safe, comfortable, and efficient operation of a vessel. By implementing proper mitigation strategies, ship designers and operators can minimize vibration and its negative consequences.