19AST203-AIRCRAFT STRUCTURAL MECHANICS

UNIT-V BUCKLING OF PLATES AND STRESS ANALYSIS

1. **Explain the pure tension field and semi tension field beam analysis and bring out their differences.**

Pure Tension Field Theory is a concept used to analyze the behavior of web panels in thin-walled structures, particularly in beams subjected to shear forces. When a web panel is subjected to high shear stresses, it eventually buckles. After buckling, the panel can still carry additional load through a mechanism known as tension field action. Here's a detailed explanation:

1. **Buckling and Post-Buckling Behavior**:
   - When the shear force in a beam reaches a critical value, the web panel buckles, losing its initial stiffness.
   - After buckling, the web doesn't carry significant compressive stress; instead, it acts in tension along the diagonal direction of the shear force.
2. **Tension Field Action**:
   - Post-buckling, the web forms diagonal tension fields that can carry additional load.
   - The diagonal tension effectively transmits the shear force across the panel.
3. **Assumptions**:
   - The web panel is thin and can buckle easily.
   - The flanges and stiffeners remain elastic and are capable of carrying compressive forces.
   - The web behaves like a membrane, with negligible bending stiffness in the post-buckling stage.
4. **Applications**:
   - Commonly used in the analysis of thin-walled structures like aircraft wings, bridges, and building frameworks.

Semi Tension Field Theory

Semi Tension Field Theory is a more refined approach that combines both the shear buckling resistance of the web and the tension field action. This theory recognizes that not all the load is transferred via pure tension fields and accounts for the combined contribution of the pre- and post-buckling behavior.

1. **Combination of Shear and Tension**:
   - Before buckling, the web resists shear through its shear stiffness.
   - After buckling, the web still contributes to load-carrying capacity through tension field action, but the initial shear stiffness is also considered.
2. **Partial Shear Resistance**:

- Unlike pure tension field theory, this approach assumes that some portion of the shear force is resisted by the web in its pre-buckling stage.
- The rest of the shear is taken up by the tension fields after buckling.

3. **Elastic and Inelastic Behavior**:
   - This theory often incorporates both elastic and inelastic behavior of materials, providing a more accurate prediction of the structural response under high shear forces.
4. **Assumptions**:
   - The web can carry some shear force before buckling.
   - The transition from pre-buckling shear resistance to post-buckling tension field action is gradual.
   - The contribution of flanges and stiffeners is also considered.

Differences Between Pure Tension Field and Semi Tension Field Theories

1. **Load Distribution**:
   - **Pure Tension Field**: Assumes that the entire load is transferred through tension fields after buckling, with negligible shear resistance from the web.
   - **Semi Tension Field**: Accounts for both shear resistance in the pre-buckling stage and tension field action post-buckling, providing a more comprehensive load distribution.
2. **Assumptions on Web Behavior**:
   - **Pure Tension Field**: Assumes the web behaves like a membrane with no bending stiffness after buckling.
   - **Semi Tension Field**: Considers both shear stiffness before buckling and membrane action after buckling.
3. **Accuracy and Complexity**:
   - **Pure Tension Field**: Simpler to apply but less accurate as it doesn't consider the initial shear resistance of the web.
   - **Semi Tension Field**: More complex and accurate as it combines the effects of shear and tension field actions.
4. **Material and Geometric Considerations**:
   - **Pure Tension Field**: Generally applies to very thin webs where buckling occurs at low shear forces.
   - **Semi Tension Field**: Can be applied to a broader range of web thicknesses and materials, considering both buckling and post-buckling behaviors.

2. **What categories of weights does an airplane have to be classified for and what does this mean? Draw an illustration of these loads acting on an aircraft.**

In aviation, the weight classification of an airplane is crucial for understanding its performance, safety, and operational limits. These weight classifications are typically broken down into several categories, each representing different stages and conditions of flight. Here are the main categories:

Categories of Weights

1. **Basic Empty Weight (BEW)**:
   - **Definition**: The weight of the aircraft "as built" including the airframe, engine, permanently installed equipment, and unusable fuel and oil.
   - **Importance**: Provides a starting point for weight calculations and is essential for determining payload capacity.
2. **Operating Empty Weight (OEW)**:
   - **Definition**: BEW plus the weight of the crew, their baggage, and other standard items like engine oil, and sometimes water and catering equipment.
   - **Importance**: Used to calculate the basic operational state of the aircraft before loading passengers and cargo.
3. **Maximum Zero Fuel Weight (MZFW)**:
   - **Definition**: The maximum weight of the aircraft with no usable fuel. It includes the OEW plus the payload (passengers, cargo, and baggage).
   - **Importance**: Ensures the structural integrity of the aircraft without the influence of fuel weight.
4. **Maximum Takeoff Weight (MTOW)**:
   - **Definition**: The maximum allowable weight for takeoff.
   - **Importance**: Critical for determining the aircraft's performance capabilities, including required runway length and climb performance.
5. **Maximum Landing Weight (MLW)**:
   - **Definition**: The maximum weight at which the aircraft can safely land.
   - **Importance**: Ensures the aircraft's structural integrity during landing and determines necessary runway length and landing performance.
6. **Maximum Ramp Weight (MRW)**:
   - **Definition**: The maximum weight allowed while the aircraft is on the ground, also known as the taxi weight.
   - **Importance**: Accounts for additional weight due to fuel burn during taxi

   Description of the Loads Acting on an Aircraft

   - **Lift**:
   - **Source**: Generated by the wings.
   - **Direction**: Acts upwards, counteracting weight.
   - **Importance**: Essential for maintaining altitude and counterbalancing the gravitational force.
   - **Weight**:
   - **Source**: Gravitational force acting on the mass of the aircraft.
   - **Direction**: Acts downwards towards the center of the Earth.
   - **Importance**: The sum of BEW, payload, fuel, etc., that the lift must counteract to maintain flight.
   - **Thrust**:

- **Source**: Produced by the aircraft's engines.
- **Direction**: Acts forward.
- **Importance**: Overcomes drag and propels the aircraft forward.
- **Drag**:
- **Source**: Air resistance and friction.
- **Direction**: Acts backward, opposing thrust.
- **Importance**: Must be overcome by thrust for the aircraft to accelerate and maintain speed.
- These forces and weight categories must be carefully balanced and managed to ensure safe and efficient flight operations. Understanding and calculating these weights are essential for pilots, engineers, and aviation planners.
- operations before takeoff.

3. **What are the types of loads that an aircraft is subject to classify and explain these loads? Sketch and indicate how these loads act on an aircraft.**

An aircraft is subject to various types of loads during its operation, each affecting its structure and performance. These loads can be broadly classified into the following categories:

Types of Loads on an Aircraft

1. **Static Loads**
2. **Dynamic Loads**
3. **Aerodynamic Loads**
4. **Inertial Loads**
5. **Ground Loads**

Let's discuss each type in detail and illustrate how these loads act on an aircraft.

1. Static Loads

Definition: Loads that do not change with time or change very slowly. They are typically constant or steady forces acting on the aircraft.

Examples:

- Weight of the aircraft (gravitational load).
- Loads due to the aircraft's own weight when it is parked on the ground.

How They Act:

- Act vertically downward due to gravity.
- Cause compression or tension in the aircraft's structure.

4. Enumerate the various structural components found in an airplane semi-monologue wing. What roles do they play? Carefully sketch the wing diagram.

5. List out the different structural elements contained in an aircraft semi- monologue wing. What are their functions? Draw the wing diagram neatly.
6. Describe the differences between the pure tension field and semi-tension field beam analyses.

2. Dynamic Loads

Definition: Loads that change with time, often rapidly. These loads can result from maneuvers, gusts, or other transient events.

Examples:

- Loads during takeoff and landing.
- Turbulence or gust loads.
- Maneuver loads during turns or other dynamic flight operations.

How They Act:

- Can act in various directions, often cyclic or transient in nature.
- Cause vibration, fatigue, and dynamic stress in the aircraft's structure.

3. Aerodynamic Loads

Definition: Loads generated by the interaction between the aircraft and the surrounding air. These include lift, drag, and moments caused by airflow over the wings and body.

Examples:

- Lift generated by the wings.
- Drag acting opposite to the direction of motion.
- Aerodynamic moments causing pitching, rolling, or yawing.

How They Act:

- Lift acts perpendicular to the relative airflow.
- Drag acts parallel and opposite to the direction of flight.
- Moments cause rotational forces about the aircraft's center of gravity.

4. Inertial Loads

Definition: Loads resulting from the aircraft's acceleration or deceleration. These are due to inertia and are experienced during changes in velocity or direction.

Examples:

- Loads during acceleration and deceleration in takeoff and landing.
- Centrifugal forces during turns.
- Loads due to sudden changes in velocity or direction (e.g., turbulence).

How They Act:

- Act in the direction opposite to acceleration.
- Affects the distribution of weight within the aircraft.

5. Ground Loads

Definition: Loads experienced by the aircraft while on the ground. These include the forces during taxiing, takeoff, and landing.

Examples:

- Impact loads during landing.
- Rolling loads during taxiing.
- Static loads when parked.

How They Act:

- Act vertically upward through the landing gear during ground operations.
- Cause compression and bending stresses in the landing gear and lower fuselage.

4. Enumerate the various structural components found in an airplane semi-monologue wing. What roles do they play? Carefully sketch the wing diagram.

In an airplane semi-monocoque wing structure, various components work together to provide the necessary strength, rigidity, and aerodynamic efficiency. Here are the main structural components found in a semi-monocoque wing and their roles:

Structural Components

1. Spars
2. Ribs
3. Stringers
4. Skin
5. Wing Box
6. Wing Root
7. Wing Tip
8. Fuel Tanks
9. Flaps
10. Ailerons
11. Wing Struts (if applicable)

Let's discuss each component and its role.

1. Spars

Role: The main structural members of the wing that run spanwise (from the wing root to the wing tip). They bear most of the bending and shear stresses.

2. Ribs

Role: Run chordwise (from the leading edge to the trailing edge) and provide shape to the wing. They also distribute loads from the skin and stringers to the spars.

3. Stringers

Role: Run spanwise between the ribs. They provide additional support to the skin, helping to prevent buckling and distributing aerodynamic loads.

4. Skin

Role: The outer surface of the wing that provides aerodynamic smoothness and transfers aerodynamic loads to the internal structure (spars, ribs, and stringers).

5. Wing Box

Role: The primary load-bearing structure within the wing, typically formed by the spars, ribs, and skin. It carries most of the structural loads.

6. Wing Root

Role: The section of the wing closest to the fuselage. It is structurally reinforced to handle the significant loads transferred from the wing to the fuselage.

7. Wing Tip

Role: The outermost part of the wing, often designed with devices like winglets to reduce drag and improve aerodynamic efficiency.

8. Fuel Tanks

Role: Often integrated within the wing structure, these tanks store fuel and help in balancing the aircraft's weight.

9. Flaps

Role: Control surfaces located on the trailing edge of the wing, used to increase lift during takeoff and landing.

10. Ailerons

Role: Control surfaces on the trailing edge, near the wing tips, used to control the aircraft's roll.

11. Wing Struts (if applicable)

Role: Additional supports in some aircraft designs (typically high-wing) that connect the wing to the fuselage for added structural support.

6. Describe the differences between the pure tension field and semi-tension field beam analyses.

The pure tension field and semi-tension field beam analyses are two methods used to analyze the behavior of thin-walled structures, such as web panels in beams, under shear loads. Both approaches deal with the post-buckling behavior of the web, but they differ in their assumptions and treatment of how the web carries loads after buckling.

Pure Tension Field Theory

Concept:

- This theory assumes that after the web panel buckles due to shear load, it can no longer carry compressive stresses and instead carries all additional loads through diagonal tension fields.

Assumptions:

- The web behaves like a membrane with negligible bending stiffness in the post-buckling stage.
- All post-buckling shear loads are transferred through diagonal tension.
- The web is considered to have buckled completely, and only tensile stresses are considered in the web.

Characteristics:

- Simplifies the analysis by assuming that the entire load is transferred through tension fields in the post-buckling state.
- Neglects the initial shear stiffness of the web before buckling.
- Often leads to conservative designs, as it assumes that the web contributes nothing to shear resistance after buckling.

Semi-Tension Field Theory

Concept:

- This theory provides a more nuanced approach by considering both the pre-buckling shear resistance of the web and the post-buckling tension field action.

Assumptions:

- The web can carry some shear force before buckling.
- After buckling, the web still contributes to load-carrying capacity through tension field action, but the initial shear stiffness is also taken into account.
- The transition from pre-buckling shear resistance to post-buckling tension field action is gradual and accounts for both contributions.

Characteristics:

- Combines the effects of shear and tension field actions for a more comprehensive load distribution.
- Considers both the elastic behavior of the web before buckling and the tension field action after buckling.
- Results in a more accurate and less conservative design compared to pure tension field theory.

- Often includes both elastic and inelastic behavior of materials, making it more complex but also more representative of actual structural behavior.

Differences

1. **Load Distribution**:
   - **Pure Tension Field**: Assumes that the entire load is carried by diagonal tension fields after buckling.
   - **Semi-Tension Field**: Considers both pre-buckling shear resistance and post-buckling tension fields, distributing the load between these two mechanisms.
2. **Web Behavior**:
   - **Pure Tension Field**: Treats the web as a membrane with negligible post-buckling shear resistance.
   - **Semi-Tension Field**: Accounts for the web's ability to carry shear load before buckling and the contribution of tension fields after buckling.
3. **Accuracy and Complexity**:
   - **Pure Tension Field**: Simpler and more conservative, potentially leading to over-designed structures.
   - **Semi-Tension Field**: More complex and accurate, providing a balanced approach that avoids overly conservative designs.
4. **Structural Design Implications**:
   - **Pure Tension Field**: May result in heavier and more robust designs due to conservative assumptions.
   - **Semi-Tension Field**: Allows for more optimized designs by accurately reflecting the web's load-carrying capacity throughout its loading history.