

An Investigation on Structural Stability for Aerospace Structures

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ABSTRACT: An aircraft is a device that is used for, or is intended to be used for, flight in the air. Major categories of aircraft are airplane, rotorcraft, glider, and lighter-than-air vehicles. The paper attempts a broad overview of the vast field of stability of structures, including elastic and an elastic structure, static and dynamic response, linear and non-linear behaviour, energy approach, thermodynamic aspects, creep stability and fracture or damage-induced instability. The principal accomplishments are succinctly reviewed, and fruitful recent trends, particularly the stability analysis of damage localization and fracture, are emphasized.

KEYWORDS: fuselage, wings, stabilizers, Landing gear, etc

I. INTRODUCTION

The airframe of a fixed-wing aircraft consists of five principal units: the fuselage, wings, stabilizers, flight control surfaces, and landing gear. Helicopter airframes consist of the fuselage, main rotor and related gearbox, tail rotor, and the landing gear. Airframe structural components are constructed from a wide variety of materials. The earliest aircraft were constructed primarily of wood. Steel tubing and the most common material, aluminium, followed. Structural members of an aircraft's fuselage include stringers, longerons, ribs, bulkheads, and more. The main structural member in a wing is called the wing spar. The skin of aircraft can also be made from a variety of materials, ranging from impregnated fabric to plywood, aluminium, or composites. Under the skin and attached to the structural fuselage are the many components that support airframe function.

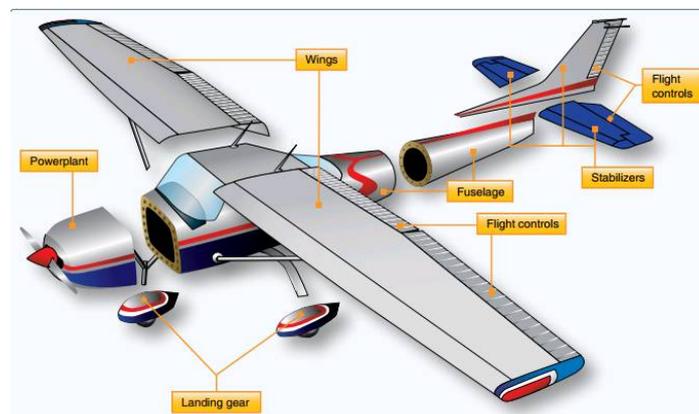


Fig.1. Aircraft Components

The airframe of a fixed-wing aircraft consists of the following five major units: 1. Fuselage 2. Wings 3. Stabilizers 4. Flight controls surfaces 5. Landing gear
A rotary-wing aircraft consists of the following four major units:

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1. Fuselage
2. Landing gear
3. Main rotor assembly
4. Tail rotor assembly

1. FUSELAGE

The fuselage is the main structure, or body, of the aircraft. It provides space for personnel, cargo, controls, and most of the accessories. The power plant, wings, stabilizers, and landing gear are attached to it. There are two general types of fuselage construction: welded steel truss and monocoque designs. The welded steel truss was used in smaller Navy aircraft, and it is still being used in some helicopters. The monocoque design relies largely on the strength of the skin, or covering, to carry various loads. The monocoque design may be divided into three classes: monocoque, semi-monocoque, and reinforced shell.

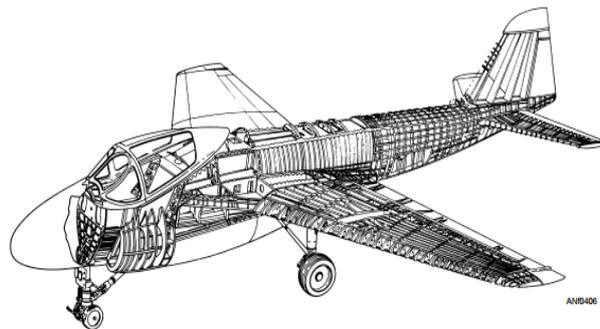


Fig.2. Semi monocoque fuselage construction.

2. WINGS

Wings develop the major portion of the lift of a heavier-than-air aircraft. Wing structures carry some of the heavier loads found in the aircraft structure. The particular design of a wing depends on many factors, such as the size, weight, speed, rate of climb, and use of the aircraft. The wing must be constructed so that it holds its aerodynamic shape under the extreme stresses of combat maneuvers or wing loading.

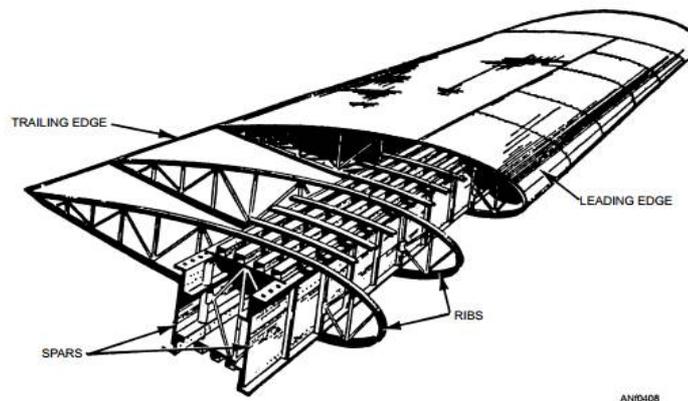


Fig. 3. Two-spar wing construction.

3. STABILIZERS

The stabilizing surfaces of an aircraft consist of vertical and horizontal airfoils. They are called the *vertical stabilizer* (or *fin*) and *horizontal stabilizer*. These two airfoils, along with the rudder and elevators, form the tail section. For inspection and maintenance purposes, the entire tail section is considered a single unit called the *empennage*. The main purpose of stabilizers is to keep the aircraft in straight-and-level flight.

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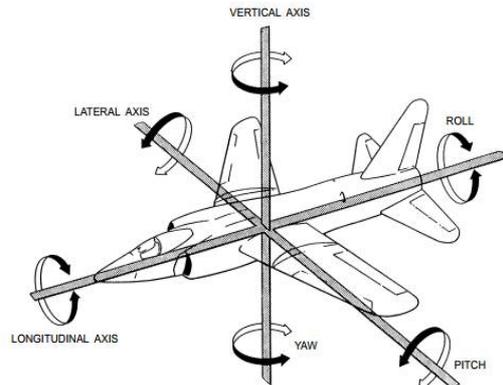


Fig.4. Axes and fundamental movements of the aircraft.

4. FLIGHT CONTROL SURFACES

Flight control surfaces are hinged (movable) airfoils designed to change the attitude of the aircraft during flight. These surfaces are divided into three groups—primary, secondary, and auxiliary.

Primary Group

The primary group of flight control surfaces includes ailerons, elevators, and rudders. The ailerons attach to the trailing edge of the wings. They control the rolling (or banking) motion of the aircraft. This action is known as *longitudinal control*.

Secondary Group

The secondary group includes the trim tabs and spring tabs. Trim tabs are small airfoils recessed into the trailing edges of the primary control surface. Each trim tab hinges to its parent primary control surface, but operates by an independent control. Trim tabs let the pilot trim out an unbalanced condition without exerting pressure on the primary controls.

Auxiliary Group

The auxiliary group includes the wing flaps, spoilers, speed brakes, and slats.

WING FLAPS.—Wing flaps give the aircraft extra lift. Their purpose is to reduce the landing speed. Reducing the landing speed shortens the length of the landing rollout. Flaps help the pilot land in small or obstructed areas by increasing the glide angle without greatly increasing the approach speed. The use of flaps during takeoff serves to reduce the length of the takeoff run.

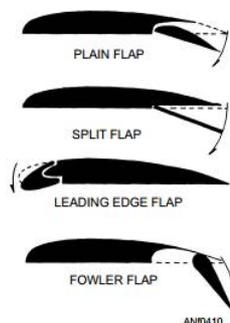


Fig.5. Types of flaps.

SPOILERS.—Spoilers are used to decrease wing lift. The specific design, function, and use vary with different aircraft.

SPEED BRAKES.—Speed brakes are movable control surfaces used for reducing the speed of the aircraft.

SLATS.—Slats are movable control surfaces that attach to the leading edge of the wing. When the slat is retracted, it forms the leading edge of the wing.

5. LANDING GEAR

Before World War II, aircraft were made with their main landing gear located behind the center of gravity. An auxiliary gear under the fuselage nose was added. This arrangement became known as the *tricycle type of landing gear*. Nearly all present-day Navy aircraft are equipped with tricycle landing gear. The tricycle gear has the following advantages over older landing gear:

- More stable in motion on the ground
- Maintains the fuselage in a level position
- Increases the pilot's visibility and control
- Makes landing easier, especially in cross winds

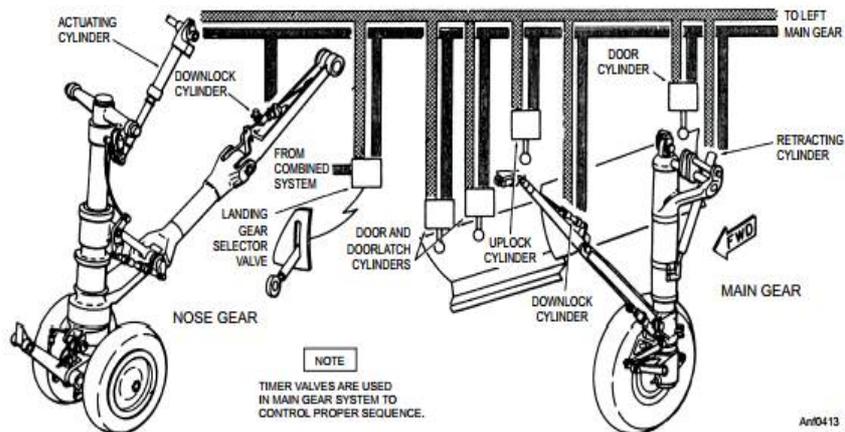


Fig. 6. Typical landing gear system.

MAIN ROTOR ASSEMBLY

The main rotor (rotor wing) and rotor head (hub assembly) are identical in theory of flight but differ in engineering or design. They are covered here because their functions are closely related. The power plant, transmission, drive-train, hydraulic flight control, and rotor systems all work together. Neither has a function without the other.

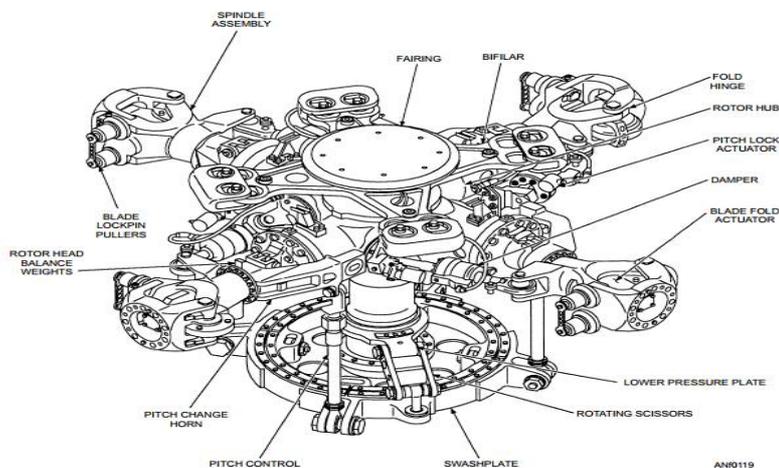


Fig. 7. Main rotor head/hub assembly.

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TAIL ROTOR GROUP

The directional control and antitorque action of the helicopter is provided by the tail rotor group.

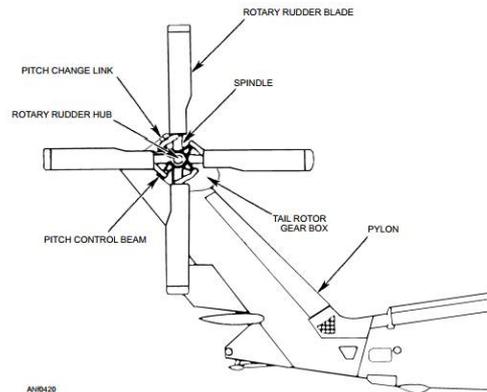


Fig. 8. Tail rotor group.

II. LITERATURE SURVEY

Structural stability Zdeněk P. Bazant* Walter P. Murphy Professor of Civil Engineering and Materials Science, Northwestern University, 2145 Sheridan Road, Evanston, IL60208-3109, USA

The paper attempts a broad overview of the vast field of stability of structures, including elastic and anelastic structures, static and dynamic response, linear and non-linear behavior, energy approach, thermodynamic aspects, creep stability and fracture or damage-induced instability. The importance of stability theory to various fields of engineering and applied science is pointed out and the history of the discipline is briefly sketched. The principal accomplishments are succinctly reviewed, and fruitful recent trends, particularly the stability analysis of damage localization and fracture, are emphasized. Only selected references are given. © 1999 Elsevier Science Ltd. All rights reserved.

Future structural stability design for composite space and airframe structures R. Degenhardt* †, a. Kling*

European space and aircraft industry demands for reduced development and operating costs. Structural weight reduction by exploitation of structural reserves in composite space and aerospace structures contributes to this aim, however, it requires accurate and experimentally validated stability analysis of real structures under realistic loading conditions. This paper presents different advances from the area of structural stability analysis of composite aerospace structures which contribute to that field.

III. STRUCTURAL STRESS

The primary factors to consider in aircraft structures are strength, weight, and reliability. These factors determine the requirements to be met by any material used to construct or repair the aircraft. Airframes must be strong and light in weight. An aircraft built so heavy that it couldn't support more than a few hundred pounds of additional weight would be useless. All materials used to construct an aircraft must be reliable. Reliability minimizes the possibility of dangerous and unexpected failures. Many forces and structural stresses act on an aircraft when it is flying and when it is static. When it is static, the force of gravity produces weight, which is supported by the landing gear. The landing gear absorbs the forces imposed on the aircraft by take-offs and landings. During flight, any manoeuvre that causes acceleration or deceleration increases the forces and stresses on the wings and fuselage. Stresses on the wings, fuselage, and landing gear of aircraft are tension, compression, shear, bending, and torsion. These stresses are absorbed by each component of the wing structure and transmitted to the fuselage structure. The empennage (tail section) absorbs the same stresses and transmits them to the fuselage. These stresses are known as *loads*, and the study of loads is called a *stress analysis*. Stresses are analysed and considered when an aircraft is designed. The stresses acting on an aircraft are shown in figure 9.

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TENSION

Tension (fig. 9, view A) is defined as *pull*. It is the stress of stretching an object or pulling at its ends. Tension is the resistance to pulling apart or stretching produced by two forces pulling in opposite directions along the same straight line. For example, an elevator control cable is in additional tension when the pilot moves the control column.

COMPRESSION

If forces acting on an aircraft move toward each other to squeeze the material, the stress is called *compression*. Compression (fig. 9, view B) is the opposite of tension. Tension is **pull**, and compression is **push**. Compression is the resistance to crushing produced by two forces pushing toward each other in the same straight line. For example, when an airplane is on the ground, the landing gear struts are under a constant compression stress.

SHEAR

Cutting a piece of paper with scissors is an example of a shearing action. In an aircraft structure, shear (fig.9, view D) is a stress exerted when two pieces of fastened material tend to separate. Shear stress is the outcome of sliding one part over the other in opposite directions. The rivets and bolts of an aircraft experience both shear and tension stresses.

BENDING

Bending (fig. 9, view E) is a combination of tension and compression. For example, when bending a piece of tubing, the upper portion stretches (tension) and the lower portion crushes together (compression). The wing spars of an aircraft in flight are subject to bending stresses.

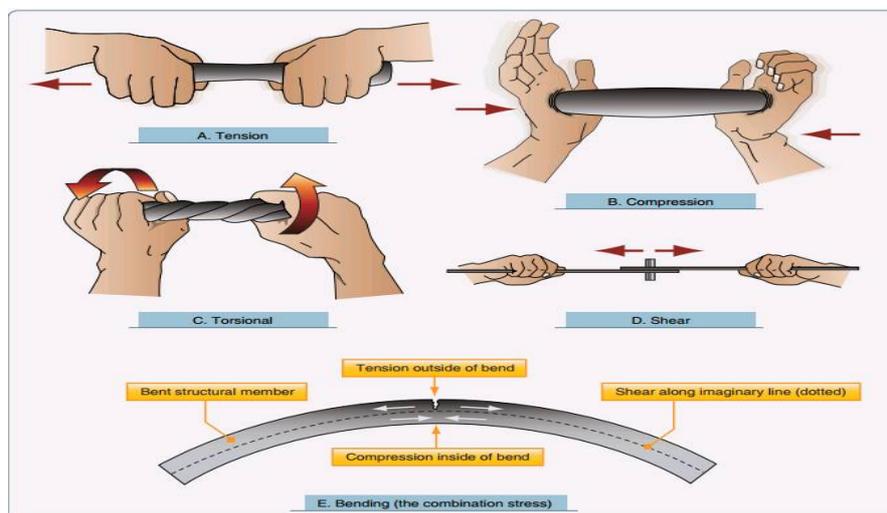


Figure 9. The five stresses that may act on an aircraft and its parts.

TORSION

Torsional (fig.9, view C) stresses result from twisting force. When you wring out a chamois skin, you are putting it under torsion. Torsion is produced in an engine crankshaft while the engine is running. Forces that produce torsional stress also produce torque.

VARYING STRESS

All structural members of an aircraft are subject to one or more stresses. Sometimes a structural member has alternate stresses; for example, it is under compression one instant and under tension the next. The strength of aircraft materials must be great enough to withstand maximum force of varying stresses.

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IV. SPECIFIC ACTION OF STRESSES

The fuselage of an aircraft is subject the five types of stress—torsion, bending, tension, shear, and compression. Torsional stress in a fuselage is created in several ways. For example, tensional stress is encountered in engine torque on turboprop aircraft. Engine torque tends to rotate the aircraft in the direction opposite to the direction the propeller is turning. This force creates torsion stress in the fuselage. Figure 3 shows the effect of the rotating propellers. Also, torsion stress on the fuselage is created by the action of the ailerons when the aircraft is maneuverer. When an aircraft is on the ground, there is a bending force on the fuselage. This force occurs because of the weight of the aircraft. Bending increases when the aircraft makes a carrier landing. This bending action creates a tension stress on the lower skin of the fuselage and a compression stress on the top skin. Bending action is shown in figure 4. These stresses are transmitted to the fuselage when the aircraft is in-flight. Bending occurs because of the reaction of the airflow against the wings and empennage. When the aircraft is in flight, lift forces act upward against the wings, tending to bend them upward. The wings are prevented from folding over the fuselage by the resisting strength of the wing structure. The bending action creates a tension stress on the bottom of the wings and a compression stress on the top of the wings.

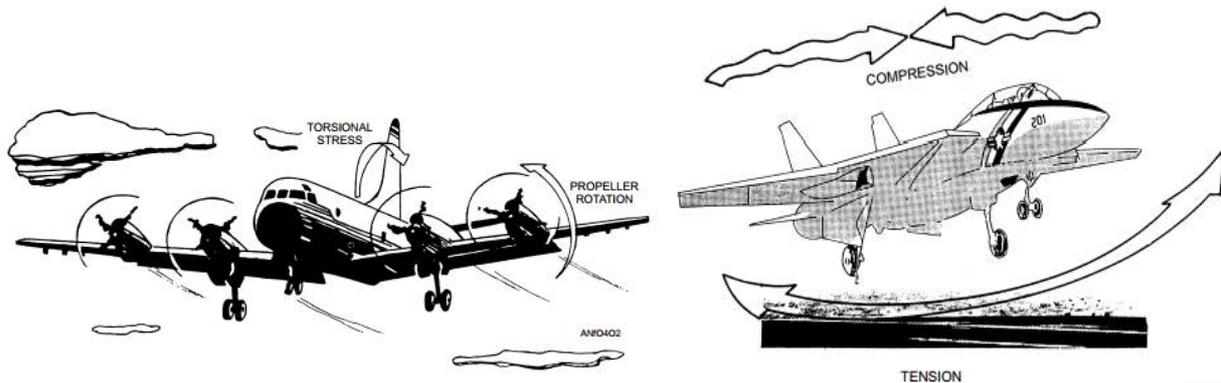


Figure 10. Engine torque creates torsion stress in aircraft fuselages. Figure 4 Bending action

V. CONSTRUCTION MATERIALS

An aircraft must be constructed of materials that are both light and strong. Early aircraft were made of wood. Lightweight metal alloys with strength greater than wood were developed and used on later aircraft. Materials currently used in aircraft construction are classified as either metallic materials or non-metallic materials.

METALLIC MATERIALS

The most common metals used in aircraft construction are aluminium, magnesium, titanium, steel, and their alloys.

- Alloys
- Aluminium
- Magnesium
- Titanium
- Steel Alloys

NONMETALLIC MATERIALS

In addition to metals, various types of plastic materials are found in aircraft construction. Some of these plastics include transparent plastic, reinforced plastic, composite, and carbon-fibre materials.

- Transparent Plastic
- Reinforced Plastic

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VI. CONCLUSION

Naval aircraft are built to meet certain specified requirements. These requirements must be selected so they can be built into one aircraft. It is not possible for one aircraft to possess all characteristics; just as it isn't possible for an aircraft to have the comfort of a passenger transport and the manoeuvrability of a fighter. The type and class of the aircraft determine how strong it must be built. A Navy fighter must be fast, manoeuvrable, and equipped for attack and defence. To meet these requirements, the aircraft is highly powered and has a very strong structure. The principal accomplishments are succinctly reviewed, and fruitful recent trends, particularly the stability analysis of damage localization and fracture, are emphasized.

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