1 General

1.1 Introduction

The contents of this book will focus on the anatomy of the aeroplane and the various systems that enable it to operate both on the ground and in the air.

Typically, an aeroplane is made up of the following main component parts, *see fig. AS 1.1*:

- Fuselage (the central body)
- Wings (mainplanes)
- Horizontal stabiliser (tailplane), Vertical stabiliser (fin), all called the Empennage
- Flight controls
- Landing gear
- Powerplant (engine).

The fuselage is the central body of the aeroplane since the powerplant, wings, empennage and landing gear are attached to it. Fuselages may be manufactured using various design principles. It contains sections for flight crew, passengers, cargo and equipment. The fuselage can be made

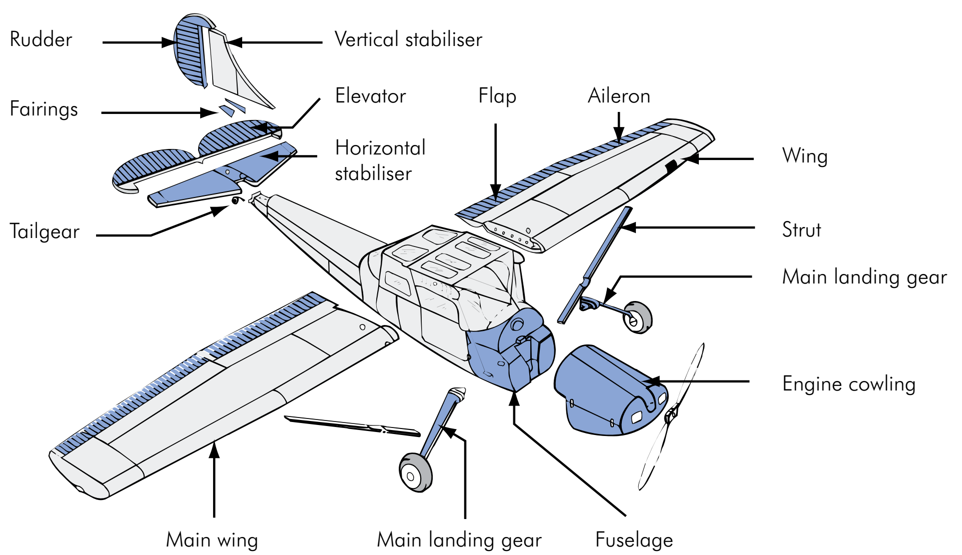

Fig. AS 1.1 Main parts of the aeroplane

from a wide range of materials which can be riveted, bolted, screwed, welded or bonded together.

We will examine the fuselage construction in more detail later, and will briefly describe some of the stresses that act on the whole aircraft structure. Additionally, we will look at the various methods of securing panels and other major structural components (wings, empennage and powerplants) to the airframe.

Meanwhile, control surfaces are attached to other main structural members such as the wings, horizontal and vertical stabilisers, by means of major hinge assemblies, or attached by load path routes direct to hydraulic or electrically operated actuators and systems.

Engines are attached to the fuselage (single engine aeroplanes) or wings by major sub frame assemblies, which may hold a turbo-prop engine ahead of the wing, and are secured to the main or auxiliary spars and ribs in the wing. Engines mounted under the wing are also attached by sub frames or pylons which are attached to wing spars by high strength bolt/pin assemblies to enable quick engine or pylon changes.

Engines attached to the rear fuselage are attached by stub wing type spars. Centre mounted engines can either be mounted directly on the fuselage or on to the vertical fin.

This chapter will also focus on the types of material that are commonly used in aircraft construction.

1.2 Design Features

Airworthiness requirements describe the safety objectives associated with failures of structural components or systems, expressed as the effects they have on the aeroplane, passengers and flight crew. The severity of the failure categories are titled:

- minor
- major
- hazardous
- catastrophic

together with their associated probabilities of occurrence per flight hour.

Table AS 1.1 is a reprint of the airworthiness requirements.

In general it can be stated: the more severe the failure condition, the lower the prescribed probability for such a condition.

One of the ways to achieve a high reliability, which is the equivalent of a low probability for a failure, is the use of redundant structural components or redundant system components. Duplication or even triplication or more of critical systems is a common design feature of large transport aeroplanes.

Failure conditions are the result of one or more causes. Airworthiness requirements demand that a catastrophic failure shall not be the result of a single failure, meaning that no single cause may result in a catastrophic failure. Redundancy is also a means to comply with this requirement.

The interpretation of the probability terms is also given in *table AS 1.1*.

Effect on Aeroplane	No effect on operational capabilities or safety	Slight reduction in functional capabilities or safety margins	Significant reduction in functional capabilities or safety margins	Large reduction in functional capabilities or safety margins	Normally with hull loss
Effect on Occupants excluding Flight Crew	Inconvenience	Physical discomfort	Physical distress, possibly including injuries	Serious or fatal injury to a small number of passengers or cabin crew	Multiple fatalities
Effect on Flight Crew	No effect on flight crew	Slight increase in workload	Physical discomfort or a significant increase in workload	Physical distress or excessive workload impairs ability to perform tasks	Fatalities or incapacitation
Allowable Qualitative Probability	No Probability Requirement	Probable	Remote	Extremely Remote	Extremely Improbable
Allowable Quantitative Probability: Average Probability per Flight Hour in the Order of:	No Probability Requirement	$<10^{-3}$	$<10^{-5}$	$<10^{-7}$	$<10^{-9}$
Classification of Failure Conditions	No Safety Effect	Minor	Major	Hazardous	Catastrophic

Table AS 1.1 Airworthiness requirements

Probable Failure Conditions are those anticipated to occur one or more times during the entire operational life of each aeroplane.

Remote Failure Conditions are those unlikely to occur to each aeroplane during its total life, but which may occur several times when considering the total operational life of a number of aeroplanes of the type.

Extremely Remote Failure Conditions are those not anticipated to occur to each aeroplane during its total life but which may occur a few times when considering the total operational life of all aeroplanes of the type.

Extremely Improbable Failure Conditions are those so unlikely that they are not anticipated to occur during the entire operational life of all aeroplanes of one type.

1.2.1 Eye Reference Position

A very important concept for flight-deck design is the eye reference position. The flight deck designer has established a position where the eye of the pilot will be during flight. The flight deck will be designed around this position and cockpit seats are adjusted such that pilots of a range of body lengths are able to bring their eyes into this position. Glareshield height, the position of indicators, pushbuttons, switches and handles are chosen, accounting for the eye reference position. Even the outside shape of the aircraft nose, including the flight deck has been influenced by the eye reference position, because during approaches there are requirements concerning the pilot's outside view. There are examples of accident investigations, where important conclusions are drawn by assuming the pilot's eyes are in that position.

There are various ways to give an indication to the pilot where the eye reference position is located in the cockpit. One method is to mount an arrangement of three balls on the centre window post. Both pilots have to position their seats such (up-down, fore-aft) that they see two balls aligned. The only possible head position that makes this possible is the eye reference position, *see fig. AS 1.2.*

Fig. AS 1.2 Eye reference position

1.3 Material Properties

Before studying the various materials used in aircraft construction some of their properties are described first. These are:

- Stress
- Strength
- Strength to density ratio
- Strain
- Elasticity and plasticity
- Limit load and ultimate load
- Stiffness
- Creep
- Fatigue.

Stress

Stress is the force applied per unit area of surface. Stress is therefore expressed in N/mm^2.

Strength

The strength of a material is its ability to withstand an applied stress without failure.

Strength to Density Ratio

The specific strength of a material is the ratio between strength and density. For this reason the specific strength is also expressed as strength-to-weight ratio or strength-to-density ratio.

Strain

A material under stress may deform. The relative amount of deformation is called strain. Strain is therefore expressed as a percentage.

Elasticity and Plasticity

The deformation can be elastic and/or plastic. Elastic deformation (or elasticity) is the property of a material to returns to its original shape after the stress has been removed.

Plastic deformation (or plasticity) is the property of a material to retain its changed shape when the applied load is removed.

Figure AS 1.3 shows elasticity and plasticity in a load-strain curve. As seen from this curve the material remains elastic throughout its working range. However if the load exceeds its elastic limit (or yield strength) it becomes plastic. When the load increases further the material will ultimately fail. Note that the load at which the material fails is less than the maximum load. This is because the strain results in contraction of the material. A lower load then already causes fracture.

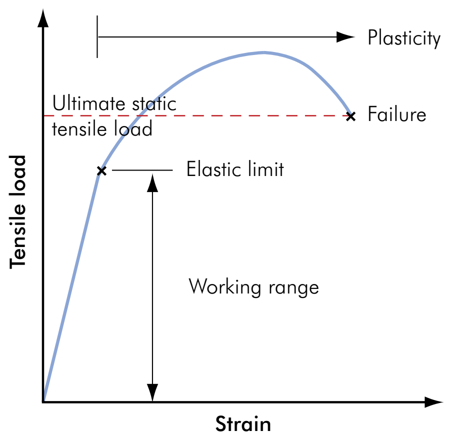

Fig. AS 1.3 Load and strain graph

Aircraft are designed so that the different structural members will not be stressed beyond their elastic limits (sometimes termed their yield point) as long as they are operated within their designated limits. Such limits are a main feature to consider in the preparation of Flight and Gust envelopes for particular aircraft types.

Another feature that should be noted from the load/strain graph, is that if the material is stressed beyond its elastic limit, although deformed, it will not immediately fail.

Limit Load and Ultimate Load

Certification requirements state that when an aeroplane is subjected to the limit load, the elastic limit of the corresponding internal stresses must not be exceeded. When the load factor reaches a higher value, called the ultimate load factor, the stresses must not exceed their point of failure. The safety is guaranteed by a safety factor of 1.5, which is the ratio of the ultimate load factor and the limit load factor. During flight operation, the limit load factor must never be exceeded.

All materials will fail when subjected to a Ultimate Load figure under static load conditions, *see fig. AS 1.3.*

If, however, a material is subjected to dynamic or moving load conditions in the form of load reversals, it is likely that it will fail at a much lower load figure than when loaded under static conditions. Such exposure and failure of materials and structures under these conditions is known as fatigue.

The Design limit load (DLL) is the maximum load that the designer expects the airframe, construction or component to experience in service.