CHAPTER 1

INTRODUCTION

Many structures such as bridges, cranes, ships, aeroplanes are commonly noticed. Each part of the structure has a definite purpose to fulfill as an individual member of that structure. In some of these structures like bridges and cranes, individual members are seen even in the completed structure. In ships and aeroplanes, the structure is covered by an outer skin and, therefore, complexity associated with the structure is not easily noticed. In the earlier planes, outer skin served twin purposes of providing smooth air flow over it and protecting the structure and payload from external environment (temperature, rain, dust,..). In modern aeroplanes, even the outer metal skin is designed to resist some external load in addition to maintaining proper shape and is to be treated as a part of the structure. Each member of the structure is designed for a particular purpose and for withstanding certain types of loads (bending, shear, torsion, axial).

Mechanical design is the design of a component for optimum size, shape, etc., ***against failure*** under the application of operational loads. A good design should also minimise the cost of material and cost of production. Failures that are commonly associated with mechanical components are broadly classified as:

(a) Failure by breaking of brittle materials and fatigue failure (when subjected to repetitive loads) of ductile materials

(b) Failure by yielding of ductile materials, subjected to non-repetitive loads

(c) Failure by elastic deformation

The last two modes cause change of shape or size of the component rendering it useless and, therefore, refer to functional or ***operational failure***. Most of the design problems refer to one of these two types of failures. Designing, thus, involves estimation of stresses of the components at different critical points of a component for the specified loads and boundary conditions, so as to satisfy operational constraints.

Design is associated with the calculation of dimensions of a component to withstand the applied loads and perform the desired function. ***Analysis*** is associated with the estimation of stresses in a component of assumed dimensions so that adequacy of assumed dimensions is validated. ***Optimum design*** is obtained by many iterations of modifying dimensions of the component based on the calculated values of stresses *vis-à-vis* permitted values and re-analysis.

An analytic method is applied to a model problem rather than to an ***actual physical problem*** (Ref Fig 1.1). Even many laboratory experiments use models. A ***geometric model*** (Ref Fig 1.2) for analysis can be devised after the physical nature of the problem has been understood. A model excludes superfluous details such as bolts, nuts, rivets, but includes all essential features, so that analysis of the model is not unnecessarily complicated and yet provides results that describe the actual problem with sufficient accuracy. A geometric model becomes a ***mathematical model*** when its behaviour is described or approximated by incorporating restrictions such as homogeneity, isotropy, constancy of material properties and mathematical simplifications applicable for small magnitudes of strains and rotations.

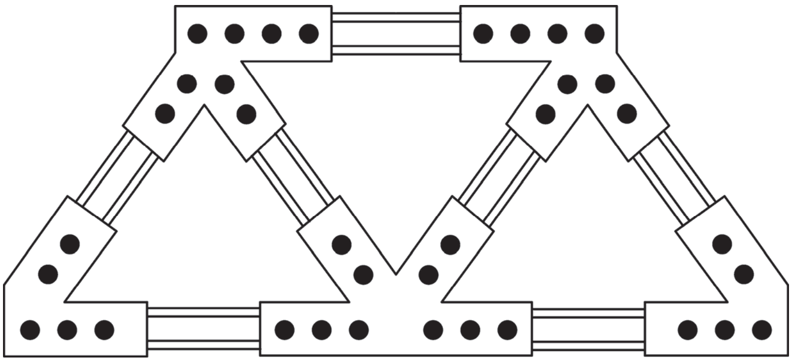

FIGURE 1.1 Physical structure of a plane truss

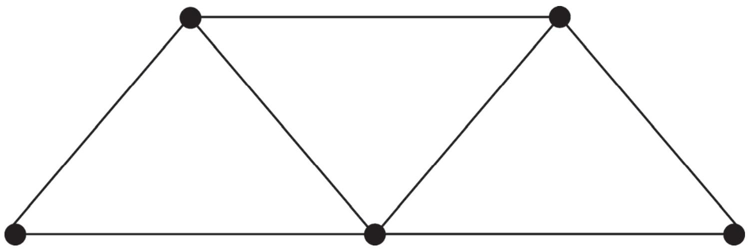

FIGURE 1.2 Geometric model of a plane truss

A review of main parts of an aeroplane and their functions are briefly covered for better appreciation of the subject in this book. Main parts of an aeroplane can be broadly classified as structure, aerodynamic and control surfaces, engine or power plant to generate lift and forward motion and avionics for effective flight control & navigation.

Type of loads and design of structural members are discussed in detail in the subsequent chapters.

1.1 SCOPE OF THIS BOOK

The subject is covered in this book in three parts. Topics, which are related to this subject and taught earlier, are briefly covered to serve as reference material to the students, whenever a need arises. Thus, basics of structural analysis covering mechanical properties of materials (Chapter-2), properties of sections (Chapter-3), mechanics of rigid bodies (Chapter-4), energy principles (Chapter-5), analysis of trusses (Chapter-6) and analysis of continuum structures (Chapter-7) are included in Part-1. These topics are covered in many universities before a student is eligible to study 'aircraft structures'.

Aircraft structures essentially consist of stiffened panels and box beams. Design and analysis of these structures is covered in sufficient detail as course material in Part-2. It starts with Design aspects of Aeroplane structure (Chapter-8) and includes Basics of aerodynamics (Chapter-9), Loads on Aeroplane structure (Chapter-10), Analysis of determinate and indeterminate beams (Chapter-11), Analysis of shafts (Chapter-12), Buckling of columns (Chapter-13), Bending and buckling of thin plates covering tension field beams and stiffened panels (Chapter-14), Shear flow, shear center and shear lag (Chapter-15), Analysis of aeroplane fuselage and wing (Chapter-16) and Fatigue Analysis (Chapter-17).

Matrix method of structural analysis was initially developed for analysing discrete structures, whose element stiffness matrices are obtained from strength of materials approach. This method has been generalised into Finite Element Method to analyse continuum structures as well as combinations of different types of elements. Element stiffness matrices are evaluated using the principle of minimum potential energy and variational principle. Analysis of any structure by this method leads to a large set of linear algebraic simultaneous equations, which can only be solved with the help of a computer. All the basic steps in the analysis of a structure by matrix method and finite element method are identical. In this background, matrix method of structural analysis is excluded from this book. Instead, finite element method is covered in sufficient detail in Chapter-19 of Part-3.

Some related topics, like Materials of aircraft construction (Chapter-18) and Aeroelasticity (Chapter-20), which are usually covered in detail as separate subjects, are also briefly covered in Part-3 for a reasonable exposure to the students.

Discussion on engine and avionics is outside the scope of this book.