



AEE 461 Design of Aircraft Structures

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Lecture #8 Connection Analysis

In this lecture, analysis methods of mechanically fastened connections are presented. Their practical applications to aircraft design are many, particularly where a load is transferred from one structural member to another. There are two basic joint arrangements that make up a connection design, as shown in Figs. 3-1 and 3-2, respectively:

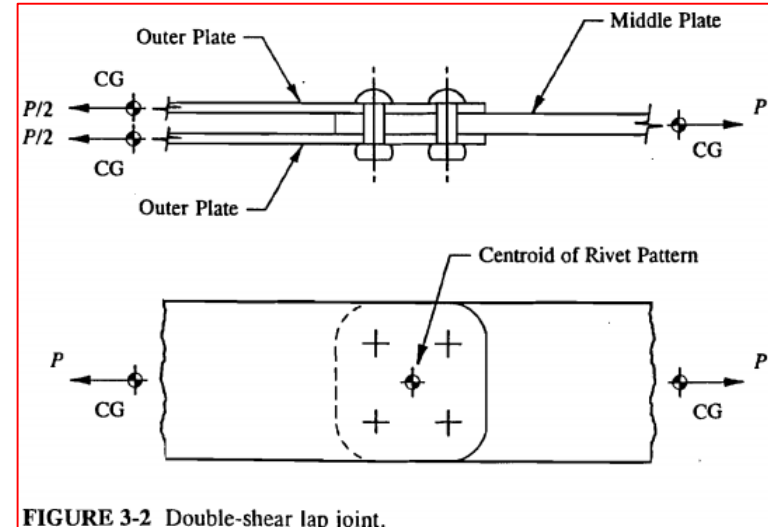
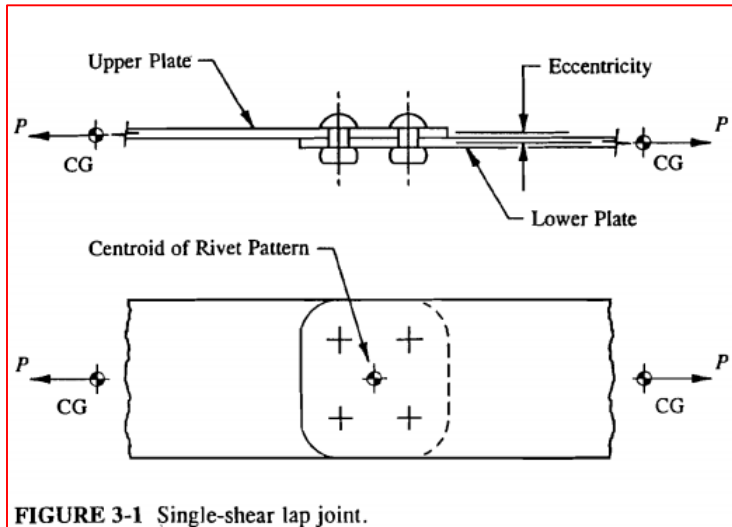
- the single-shear lap joint and
- the double-shear lap joint,

From these, a multitude of other design configurations are possible to construct for general aircraft usage such as:

- shear clips,
- brackets,
- web splices,
- support fittings,
- backup fittings,

and various types of reinforcement members that are used in conjunction with the repair and modification of in-service flight vehicle structures.

3.1 Introduction – cont'd

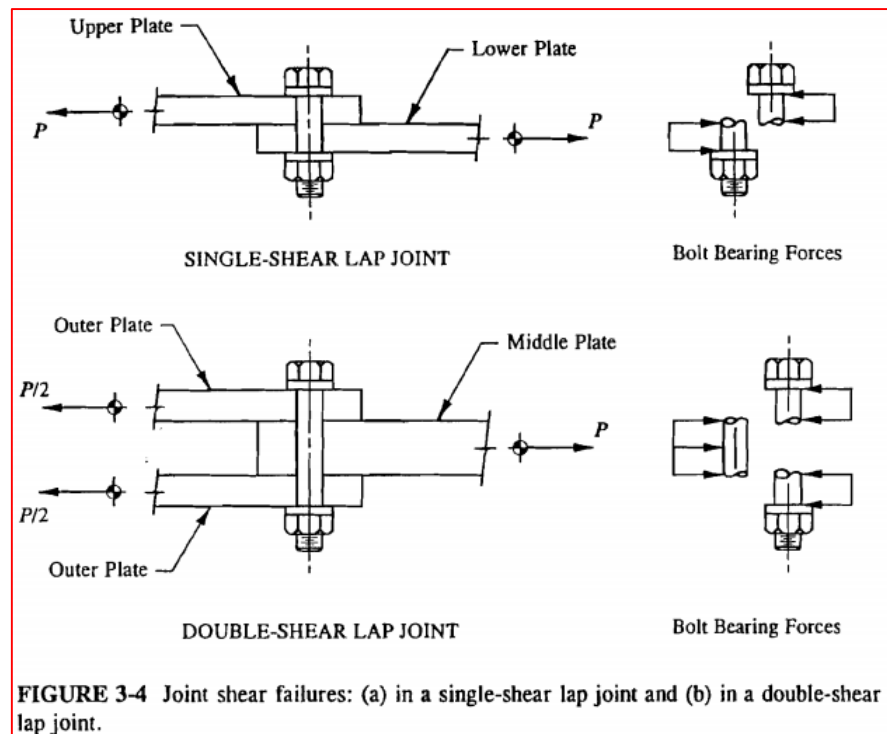
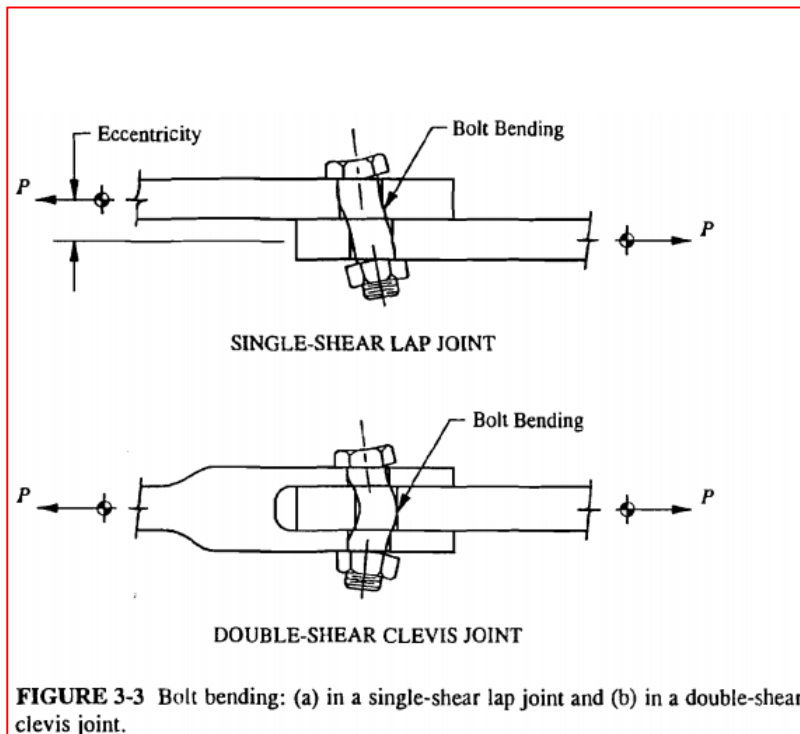


Since double-shear lap joints are composed of three or more plate-like members, they are usually of a heavier type of construction than the lighter weight two plate lap joint varieties. But since lap joints develop eccentricities of their load paths from the overlapping nature of their design configurations, the double-shear lap joint is the preferred design alternative of the two basic joint arrangements described. This condition can be clearly seen from the side view drawn of the lap joint arrangement shown in Fig. 3-1. The inherent eccentricity or offset that exists for this joint is measured (perpendicularly) between the lines of action of the plate forces.

For most commercial and military aircraft, such irregularities in joint designs are fully deliberated and taken into account by applying a prescribed fitting factor (in general 1.15 is used).

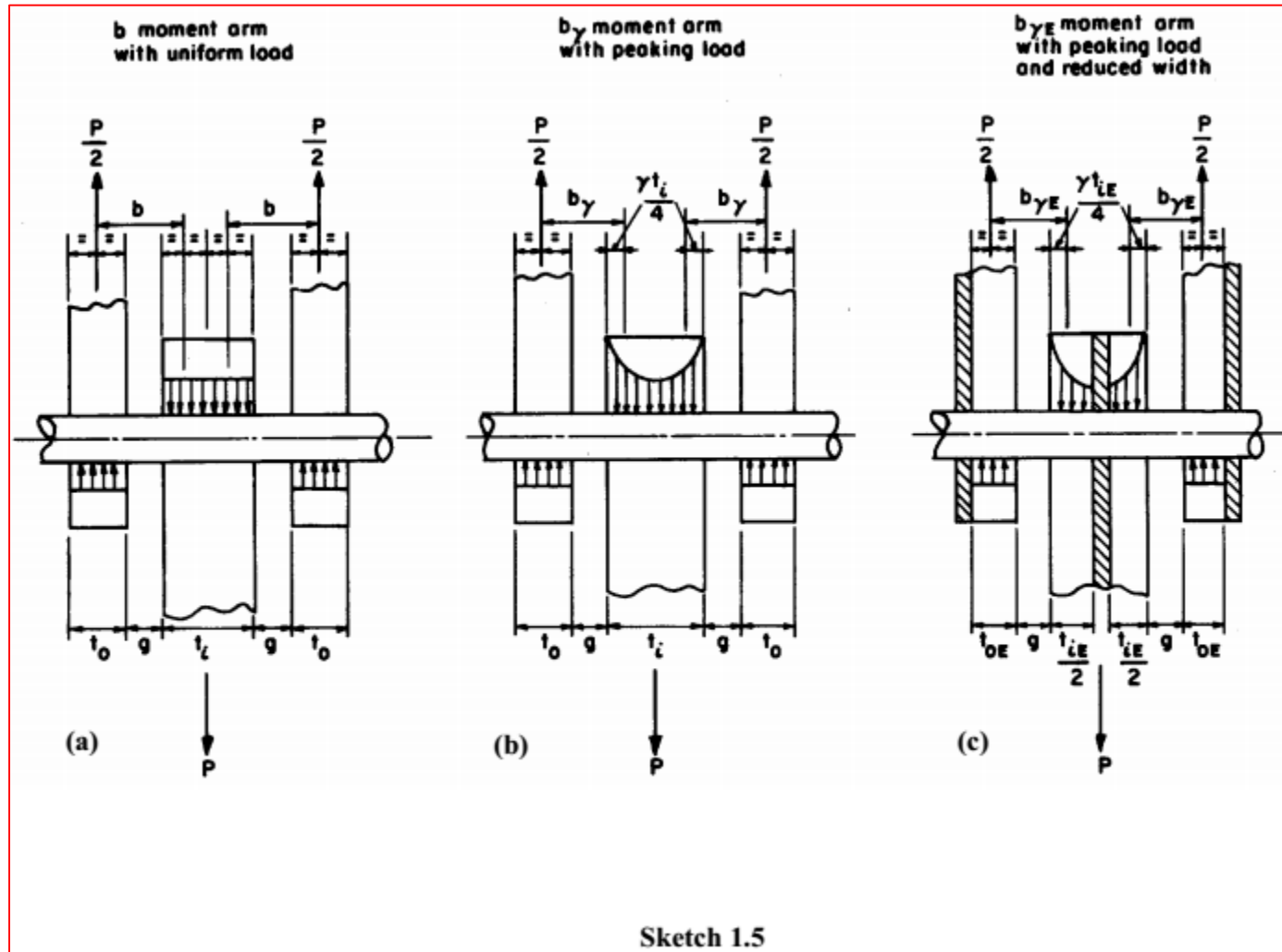
In general, if relatively thin plate-like members of either the single-shear lap or double-shear lap joint varieties are used, the local bending effect on the joint fasteners arising from the eccentricities and anomalies of their designs can be completely ignored, and therefore, disregarded from analytical consideration. Careful deliberation of thick plate-like members, however, reveals that, although a fitting factor may be applied, bending of the joint fasteners in these cases cannot be neglected. Their damaging effects must be fully considered if the effects of binding and jamming of fasteners in their holes are to be prevented. The undesirable consequences of such a design, commonly referred to as "bolt bending" should be avoided under normal operating flight and landing conditions. See Fig. 3-3 for an actual detailed description of this joint tendency. Equilibrium forces for the bolts are determined from the deflected shape of the bolts under load.

3.1 Introduction – cont'd



Static tests of single bolt fittings have shown that joint failures are principally due to failure of the lugs. However, it is bolt bending which causes the peak bearing stresses to develop on the lugs that precipitates the lugs to fail. Additionally, it is important to provide sufficient bending strength for the bolt to prevent permanent bending deformation of the bolt at limit load. In this way, the bolts can easily be removed from the structure during routine maintenance operations.

3.1 Introduction – cont'd



Ref: ESDU 91008, page 9

3.2 Strength Criteria for Mechanically Fastened Connections

The strength of a mechanically fastened joint is governed by a complement of ultimate joint failures which can occur by

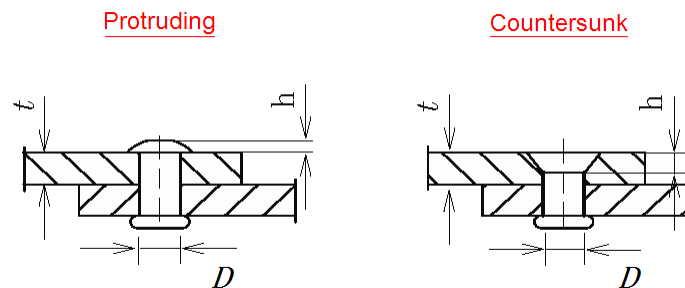
- ❑ shearing and tension failures of the fastener,
- ❑ tension and compression failures of the plate,
- ❑ bearing, shearing and tearing failures of the sheet or plate material.

Each possible mode of failure must be carefully reviewed and investigated by the analyst to assure the structural reliability and integrity of the joint design. Before the structural methods of analysis of Secs. 3.3 and 3.4 are presented, the following strength criteria established for the design of a mechanically fastened connection are defined:

Ultimate Allowable Shearing Strength P_{su} of a Solid. Protruding-Head Rivet:

The shearing failure that occurs for fasteners of both the single-shear lap joint and double-shear lap joint configurations are shown in Fig. 3-4. In either case, the bearing pressures that are developed by the plate forces bearing up against the fastener are assumed to be uniformly distributed along the fastener.

A riveted or bolted connection is primarily designed to transfer shear through its joint fasteners from one structural member to another. It is therefore the "transfer of force" that is resisted by the shear area or areas of a fastener. For a single shear lap joint, only one shear area or A_{shr} is provided by each fastener to overcome this transfer of force. In the case of a double-shear lap joint, however, two shear areas or $2A_{shr}$ are resisted by each joint fastener. In effect, it can be said that the fastener of a double-shear joint has approximately twice the strength or capacity of that same fastener if used in a single-shear joint application.



3.2 Strength Criteria for Mechanically Fastened Connections – cont'd

The ultimate allowable shearing strength of a solid, protruding-head rivet in either a single-shear or double-shear joint application, expressed in pounds (lb), is defined by the following expression:

$$P_{su} = F_{su}A_{shr}C_r$$

where: $A_{shr} = \frac{\pi}{4}D^2$ for single-shear joints; and $2A_{shr}$ for double-shear joints

F_{su} = ultimate shear stress of the rivet material (see Table 3-1 for conventional rivet types)

D = nominal hole diameter (see Table 3-1 for standard values based on the drill size of a rivet)

C_r = shear strength correction factor (see Table 3-2 for appropriate tabulated values for single-shear and double-shear joints).

3.2 Strength Criteria for Mechanically Fastened Connections – cont'd

Shearing failure is then predicted by making the following load comparison:

$$\text{Margin of Safety} = \text{M. S.} = \frac{P_{su}}{p_s} - 1$$

where p_s = ultimate shearing force of a fastener due to the applied force P (use the full load or $p_s = P$ when analyzing a fastener in either a single-shear lap joint or a double-shear lap joint) and k = fitting factor for joint design (use 1.15 for commercial and military flight vehicles).

The engineer is referred specifically to MMPDS (formerly known as MIL-HDBK-5), Sec. 8, for the static joint strength allowables of fasteners when installed in various thicknesses of different materials. Many more joint fastener allowables are also available and documented by aerospace and military standards (i.e., MS, NAS, AN), and by certain manufacturers which establish proprietary fastener specifications.