Design of Bolted Joints for General Engineering

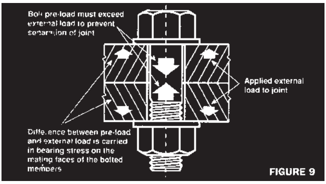

FIGURE 9

Selection of Tensile Strength of Bolts

Bolted joints in which strength is the main design consideration, can, in most cases, be more economically designed when a high tensile bolt is used rather than a mild steel bolt. Fewer bolts can be used to carry the same total load, giving rise to savings not only from the cost of a smaller number of bolts, but also machining where less holes are drilled and tapped, and assembly where less time is taken.

Selection of Coarse and Fine Threads

In practically all cases the coarse thread is a better choice. The coarse threads provide adequate strength and great advantages in assembly over fine threads. The former are less liable to become cross threaded, start more easily, particularly in awkward positions, and require less time to tighten.

In cases where fine adjustment is needed, the fine thread should be used. Providing bolts are tightened to the torque specified in Tables 18–23 there should be no tendency to loosen under conditions of vibration with either coarse or fine threads.

Types of Loading on Joints

Examine the forces being applied to the joint to decide which of the following types fits the conditions.

a) Joints carrying direct tensile loads (See Fig. 9).

b) Joints carrying loads in shear (See Fig. 10–11). Types 1 and 2.

c) Flexible gasket joints for sealing liquids or gases under pressure (See Fig. 12).

Joints Carrying Direct Tensile Loads

(1) Safety Factor. Apply a safety factor according to the nature of the loading. Except in the case of the flexible gasket joint, the safety factor on a bolt differs from most other applications in that it does not affect the stress of the bolt, but refers to the factor by which the sum of the preload on all the bolts comprising the joint exceeds the design load applied. Regardless of the nature of the load, the bolts should still be preloaded to 65% of their yield stress using the recommended torque values as set out in Table 18–23.

$$\text{Safety Factor} = \frac{\text{Sum of preload on all the bolts comprising the joint}}{\text{Design applied load}}$$

For design purposes, the preload on each bolt should be taken according to the bolt size and bolt material as shown in Tables 18 to

23 and the safety factor selected from the following table:-

Table 14

Nature of Loading	Safety Factors*
Steady Stress	1.5 – 2
Repeated Stress	
gradually applied	2 – 3.5
shock	4.5 – 6

** Applies to joints with direct tensile loads only and assumes all bolts are tightened to 65% of the yield stress.*

(2) Total Required Preload†. Determine this from safety factor (S) and applied load (L).

Total required preload F = S x L

(3) Selection of Bolt Material, Bolt Size, Number of Bolts. By selecting a suitable bolt size and bolt material, the required number of bolts can be determined from –

$$N = \frac{F}{f}$$

Where N is the number of bolts, F is the total required preload and f is the recommended preload (see Tables 18-23) on the bolt for the particular size and material selected.

(4) Specify Tightening Torque. Ensure that the bolts are fully tightened to the torque recommended in Tables 18-23 for the particular bolt size and material.

(5) Positioning of the Bolts. The bolts should be placed as near as possible to the line of direct tensile load. By doing this, secondary bending stresses in the bolts and bolted members are reduced to a minimum.

Joints Carrying Loads in Shear

The design procedure for mechanical joints carrying this type of loading can be based on well established practice laid down for structural joints carrying static loads, provided the design loads are increased by adequate factors to allow for cyclic loads, shock, etc. These factors will vary considerably according to the application, and must be based on the designer's experience. Bolted joints carrying loads in shear fall into two types:-

1. Joints in which the load is transferred through the bolted members by bearing of the member on the shank of the bolt and shear in the bolt.

2. Friction type joints, where the load is transferred by the friction developed between the members by the clamping action of the bolts.

† *Note: At time of publication there are no "Allowable Stress" code provisions for general mechanical engineering design of bolted joints. This information is provided for guidance only.*

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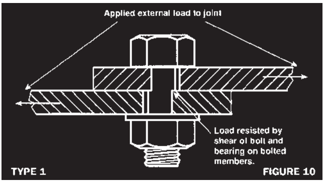
BLACKS FASTENERS



Load Transfer by Bearing and Shear

Such joints may be designed using allowable values for shear in the bolts and bearing on the joint members such as those given in AS 1250 or under the limit states provisions of AS 4100.

Guidance on bolt shear capacity is given on page 14. The lowest strength, whether it be in shear or bearing, is used to compute the required number of bolts to carry the design load.

The allowable values for shear and bearing depend not only on bolt size, but also on the tensile strength of the bolt, and whether the bolt is in a close fitting machined hole (not greater than 0.25mm clearance) or is fitted in a clearance hole (up to 2-3mm clearance).

Careful consideration should be given to the properties of the material in the bolted members to ensure they are capable of withstanding bearing loads. Tensile strength and yield stress of Blacks bolts can be obtained from Tables 5-11. Care must be taken that the pitch of the bolt spacing is sufficient to ensure that the bolted members are not weakened by the bolt holes to the extent that they cannot safely carry the load. To achieve this it may be necessary to use more than one row of bolts. Staggering of bolt holes can minimise reduction of member capacity. If more than two members are bolted together slightly higher values are permitted in bearing on the central member, and the area considered for calculating strength in shear is increased by two or four times for bolts in double or quadruple shear.

Friction Type Joints

These joints are made up using high strength bolts fitted in clearance holes and tightened under careful control to develop a preload equivalent or greater than the bolt yield load.

The mechanism of carrying load is by friction developed between the mating faces, and it is well established that this type of joint is considerably stronger than a riveted joint. Refer to Australian Standard 4100.

General Rules to Reduce Possibility of Bolt Failure Due to Fatigue

The following general rules should be observed to minimise possibility of fatigue of bolts under high alternating or fluctuating stresses.

Design of Bolted Joints for General Engineering

(1) Most Important. Tighten bolt effectively to ensure an induced tension or preload in excess of the maximum external load.

(2) Bolt extension in tightening should be high. This can be achieved by:-

a) At least 1 x bolt diameter of "free" thread length under the nut.

b) Use of small high strength bolts in preference to larger low strength bolts.

c) In extreme cases a "waisted shank" bolt can be considered.

(3) Rolled threads are preferable to machined threads.

(4) Under conditions of extreme vibration the use of locknuts such as the Conelock or Nyloc nut should be considered to avoid possibility of a loosened nut vibrating right off the bolt before detection.

(5) Bolt head and nut should be on parallel surfaces to avoid bending.

(6) Non axial bolt loading producing a "prising" action should be avoided where possible.

Flexible Gasket Joints for Sealing Liquids or Gases Under Pressure

This type of joint differs from the two preceding types in that the stress in the bolt varies with the working load.

This is because the flexible gasket material has a much lower elastic modulus than the bolt, and continues to exert virtually the same force on the bolts when additional load is applied to the joint. The resulting effect is that the working load is added to the bolt preload in this case, so the design procedure must be modified accordingly.

(1) Design Pressure Load. Determine the design load Q on the joint by multiplying the effective area A on which the pressure is acting by the liquid or gas pressure P by S where S is the safety factor selected from Table 14.

$$Q = APS$$

(2) Total Preload Required. To the design pressure load, Q add 10%, and this is the sum of the preload F that should be applied to the bolts comprising the joint.

$$F = Q + \frac{10Q}{100}$$

i.e. $F = 1.1Q$

(3) Total Design Load on Bolts. In the case of a flexible gasket type of joint the design pressure load Q on the joint is added to the preload F on the bolts, giving the total design load W on the bolts.

$W = Q + F$

(4) Select Bolt Material. From the following table of yield stresses select the bolt material.

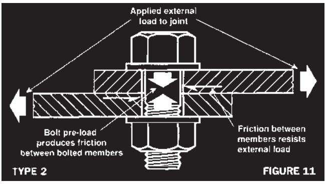


FIGURE 11

Table 15

Bolt Type	Proof Load lbf/in^2	Stress MPa
Blacks AS 2451 Bolts –		
1/4" – 3/4"	35,900	248
Over 3/4"	33,600	232
Blacks Metric Commerical Bolts	32,630	225
Blacks Metric Precision PC 8.8 Bolts	95,725	660
Blacks SAE Grade 5 High Tensile Bolts – 1/4" – 1"	85,000	586
Blacks SAE Grade 8 High Tensile Bolts	120,000	827

(5) Select Bolt Size and Determine Number of Bolts. From the desired bolt size and corresponding Stress Area "A_s", (see Tables 5-11) determine the number of bolts N from the yield stress Y and the total design load W on the bolts.

Number of bolts required $N = \frac{W}{YA_s}$

(6) Setting of Tightening Torque. In this case the bolts can only be tightened to a preload well below the yield stress so the torque figure T for the bolt size and material selected listed in Tables 18-23 must be reduced by multiplying by a factor of 0.806.

Tightening torque to be applied to bolts of a flexible gasket type of joint.

$$t = 0.8\ T$$

Metal to Metal Pressure Tight Joints

The stress in the bolts in a flexible gasket type joint varies with load, and under rapidly fluctuating loads they can be subject to fatigue. It is therefore desirable to use wherever possible, metal to metal pressure tight joints, as these are not subject to fatigue.

The design procedure for a metal to metal pressure tight joint is exactly the same as for joints carrying direct tensile loads once the pressure load is determined.

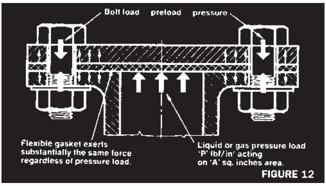


FIGURE 12