How much torque is required for proper tensioning of a bolt in a given situation? How can a given amount of work in the form of torque application be translated into the desired tension? A simplified screw jack formula by Farr shows that necessary torque is a function of the tension required, certain dimensions of the nuts and bolts, and the coefficient of friction existing on he bearing surfaces of the threads and nut faces.

$$T = \frac{F_a}{12}\left(\frac{P}{2\pi} + \frac{R_t f}{Cos\,\theta} + R_s f\right)$$

Where

T = Torque in foot - pounds

F_a = Force in pounds of tension required in bolt

P = Lead of threads, inches

R_t = Average mean radius from axis of bolt out to point where load is applied to thread surface

R_s = Mean radius of nut face, or shoulder

Cos θ = Cos of one half the included thread angle measured on a plane through axis, degrees θ usually 30°, therefore, Cos θ - 0.86603

F = Coefficient of friction (See figure 1)

All terms of this equation are fixed for any given nut and bolt size, once the tension, F_a is established, with the single exception of F, the coefficient of friction. This parameter can vary with the result that the required torque will also vary widely. The efficiency of the situation - the percentage of the effort applied to the nut that is translated into bolt tension-varies widely when the effective coefficient of friction varies.

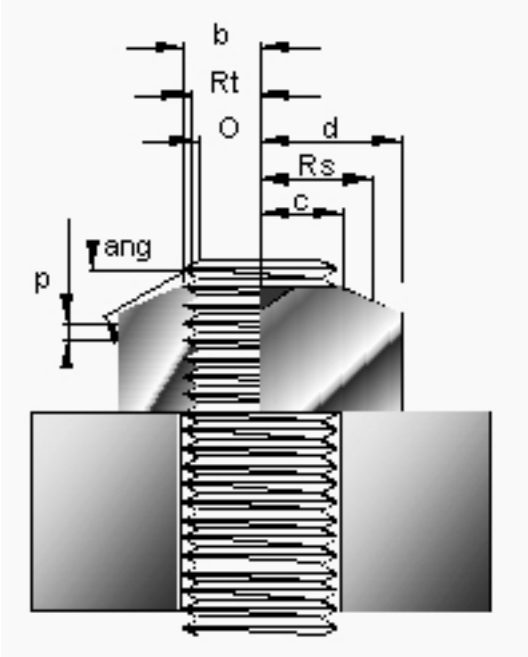

Fig 1 - A bolt (or stud) is called and externally threaded fastener and a nut is called an internally threaded fastener. The thread is and example of the inclined plane, one of the basic mechanical principals. All terms of this equation are fixed for any given nut and bolt size, once the tension, F_a is established, with the single exception of F, the coefficient of friction. This parameter can vary with the result that the required torque will also vary widely. The efficiency of the situation - the percentage of the effort applied to the nut that is translated into bolt tension-varies widely when the effective coefficient of friction varies.

The use of torque has long been associated with methods of tightening and inspecting bolts. The object of tightening bolts is to achieve a minimum *tension*, not torque, in the bolts. There is a relationship between torque and tension, but it is *highly variable* and must be used with caution.

The variables in the torque-tension relationship include lubrication, thread fit, the use of a washer and the tension in the bolt. The torque used to tighten a bolt is consumed by overcoming the friction between nut and washer (about 60%), overcoming the friction between bolt thread and nut threads (about 30%), and providing energy to elongate the bolt (about 10%). Tests have indicated that torque-tension relationships for structural bolts easily vary by as much as 40%.

The Specifications do not permit the use of *any* tabulated torque or calculated torque for either installation or inspection. Installation and inspection torques must be determined or set using Skidmore-Wilhelm (or similar) devices to establish actual tension, then determine the torque. A basic equation to *estimate* the torque-tension relationship is:

$T = 0.0167 \times P \times D$

Where
T = torque (foot-pounds)
P = bolt tension (pounds)
D = bolt diameter (inches)

The value 0.0167, called the nut factor, is a traditional industry average. It can range as low as 0.01 for well-lubricated assemblies and can exceed 0.025 for dry or rusty fasteners.

For convenience only, the following table may be used to *estimate* the torque ranges for various A325 bolts when the minimum required pretension is present. It may be used for the selection of installation and inspection tools. If bolt tensions are higher than the required minimum, torques can be correspondingly higher. Table values have been rounded. ***This table cannot be used for either installation or inspection purposes.***

A325 Approximate Torques (foot-pounds)				
A325 Bolt Diameter (inches)	**Required Tension (kips)**	**Torque**		
		Low (0.01)	**Average (0.0167)**	**High (0.025)**
1/2	12	60	100	150
5/8	19	120	200	300
3/4	28	200	350	500
7/8	39	350	550	850
1	51	500	850	1300
1-1/8	56	650	1050	1600
1-1/4	71	900	1500	2200
1-3/8	85	1150	1950	2900
1-1/2	103	1550	2600	3900

For convenience, the following table may be used to *estimate* the torque ranges for various A490 bolts when the minimum required pretension is present. It may be used for the selection of installation and inspection tools. If bolt tensions are higher than the required minimum, torques can be correspondingly higher. Table values have been rounded. ***This table cannot be used for either installation or inspection purposes.***

A490 Approximate Torques (foot-pounds)				
A490 Bolt Diameter (inches)	**Required Tension (kips)**	**Torque**		
		Low (0.01)	**Average (0.0167)**	**High (0.025)**
1/2	15	70	130	200
5/8	24	150	250	400
3/4	35	250	450	650
7/8	49	450	700	1100
1	64	650	1100	1600
1-1/8	80	900	1500	2300
1-1/4	102	1300	2100	3200
1-3/8	121	1700	2800	4200
1-1/2	148	2200	3700	5500