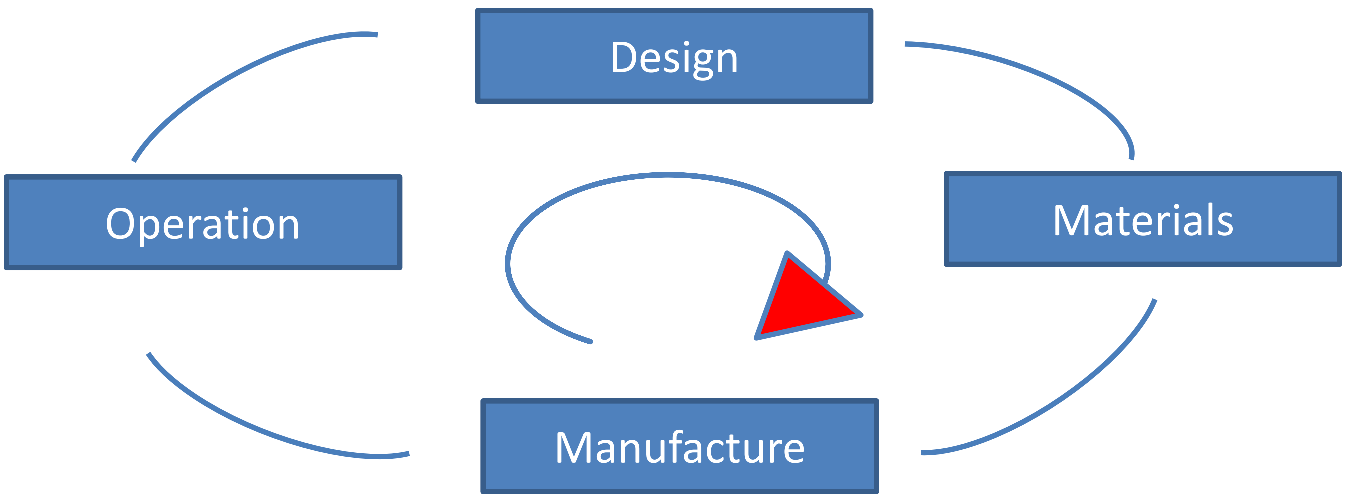
Materials for Automobiles

Lecture no 1

1 August 2011

Materials (Expectation from Design)

General	Performance Requirements	
Cost	Structural strength	Lubrication
Availability	Corrosion resistance	Adhesion
Ease of manufacture	Noise reduction	Appearance
Eco friendly	Vibration damping	
Safety		



Introduction - Classification1

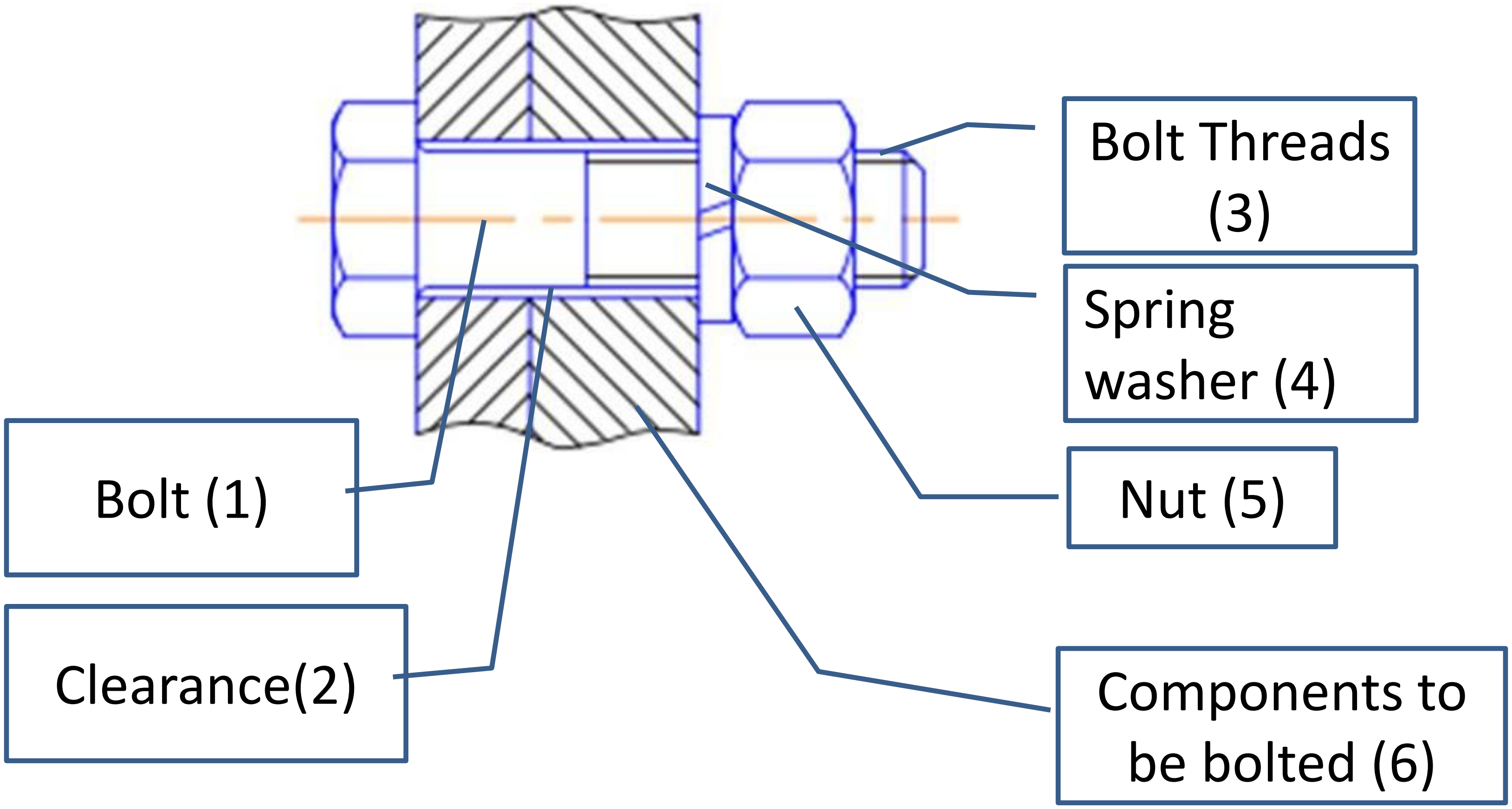
Materials	Nature	Types / Applications
Metals	Ferrous	Steels flats : • sheet/ plates • Formability/ strength combinations Wrought steel : • forgings (both carbon and low alloy) • Bar turned products Tubes and other sections Stainless steel Cast irons: GCI/ CGI/ SGI Sintered (pm)products
	Non Ferrous	Aluminium base: castings GDC/PDC/ wrought Copper base : castings/ pm
Non Metals	Rubber Plastics Lubricants Adhesives Paints Others	Hoses/ mouldings/ Injection / blow moulded / formed sheet Oils/ grease/ solid lubrication Structural , threadlocking, NVH/ vibration

Introduction – Classification 2

Materials	Types	Properties to be specified
	Materials requiring processing	• Processing properties • Properties to be obtained after processing for good service performance
	Materials procured finished (BOF)	Properties required for good service performance
	Consumables	Trade names or brands

A typical data requirement example

Bolted Joint



Bolt (1)

IS 1367 (Part 3) : 2002
ISO 898-1 : 1999

Indian Standard

TECHNICAL SUPPLY CONDITIONS FOR THREADED STEEL FASTENERS

PART 3 MECHANICAL PROPERTIES OF FASTENERS MADE OF CARBON STEEL AND ALLOY STEEL — BOLTS, SCREWS AND STUDS

(Fourth Revision)

1 Scope

This part of ISO 898 specifies the mechanical properties of bolts, screws and studs made of carbon steel and alloy steel when tested at an ambient temperature range of 10 °C to 35 °C.

Products conforming to the requirements of this part of ISO 898 are evaluated only in the ambient temperature range and may not retain the specified mechanical and physical properties at higher and lower temperatures. Attention is drawn to annex A which provides examples of lower yield stress and stress at 0,2 % non-proportional elongation at elevated temperatures.

Bolt (1)

At temperatures lower than the ambient temperature range, a significant change in the properties, particularly impact strength, may occur. When fasteners are to be used above or below the ambient temperature range it is the responsibility of the user to ensure that the mechanical and physical properties are suitable for his particular service conditions.

Certain fasteners may not fulfill the tensile or torsional requirements of this part of ISO 898 because of the geometry of the head which reduces the shear area in the head as compared to the stress area in the thread such as countersunk, raised countersunk and cheese heads (see clause 6).

This part of ISO 898 applies to bolts, screws and studs

- with coarse pitch thread M1,6 to M39, and fine pitch thread M8 × 1 to M39 × 3;
- with triangular ISO thread in accordance with ISO 68-1;
- with diameter/pitch combinations in accordance with ISO 261 and ISO 262;
- with thread tolerance in accordance with ISO 965-1 and ISO 965-2;
- made of carbon steel or alloy steel.

It does not apply to set screws and similar threaded fasteners not under tensile stresses (see ISO 898-5).

It does not specify requirements for such properties as

- weldability;
- corrosion-resistance;
- ability to withstand temperatures above + 300 °C (+ 250 °C for 10.9) or below − 50 °C;
- resistance to shear stress;
- fatigue resistance.

NOTE The designation system of this part of ISO 898 may be used for sizes outside the limits laid down in this clause (e.g. $d > 39$ mm), provided that all mechanical requirements of the property classes are met.

3 Designation system

Bolt (1)

The designation system for property classes of bolts, screws and studs is shown in table 1. The abscissae show the nominal tensile strength values, R_m, in newtons per square millimetre, while the ordinates show those of the minimum elongation after fracture, A_{min}, as a percentage.

The property class symbol consists of two figures:

- the first figure indicates 1/100 of the nominal tensile strength in newtons per square millimetre (see 5.1 in table 3);
- the second figure indicates 10 times the ratio between lower yield stress R_{eL} (or stress at 0,2 % non-proportional elongation $R_{p0,2}$) and nominal tensile strength $R_{m, nom}$ (yield stress ratio).

The multiplication of these two figures will give 1/10 of the yield stress in newtons per square millimetre.

The minimum lower yield stress $R_{eL, min}$ (or minimum stress at 0,2 % non-proportional elongation $R_{p0.2\ min}$) and minimum tensile strength $R_{m, min}$ are equal to or greater than the nominal values (see table 3).

4 Materials

Table 2 specifies steels and tempering temperatures for the different property classes of bolts, screws and studs.

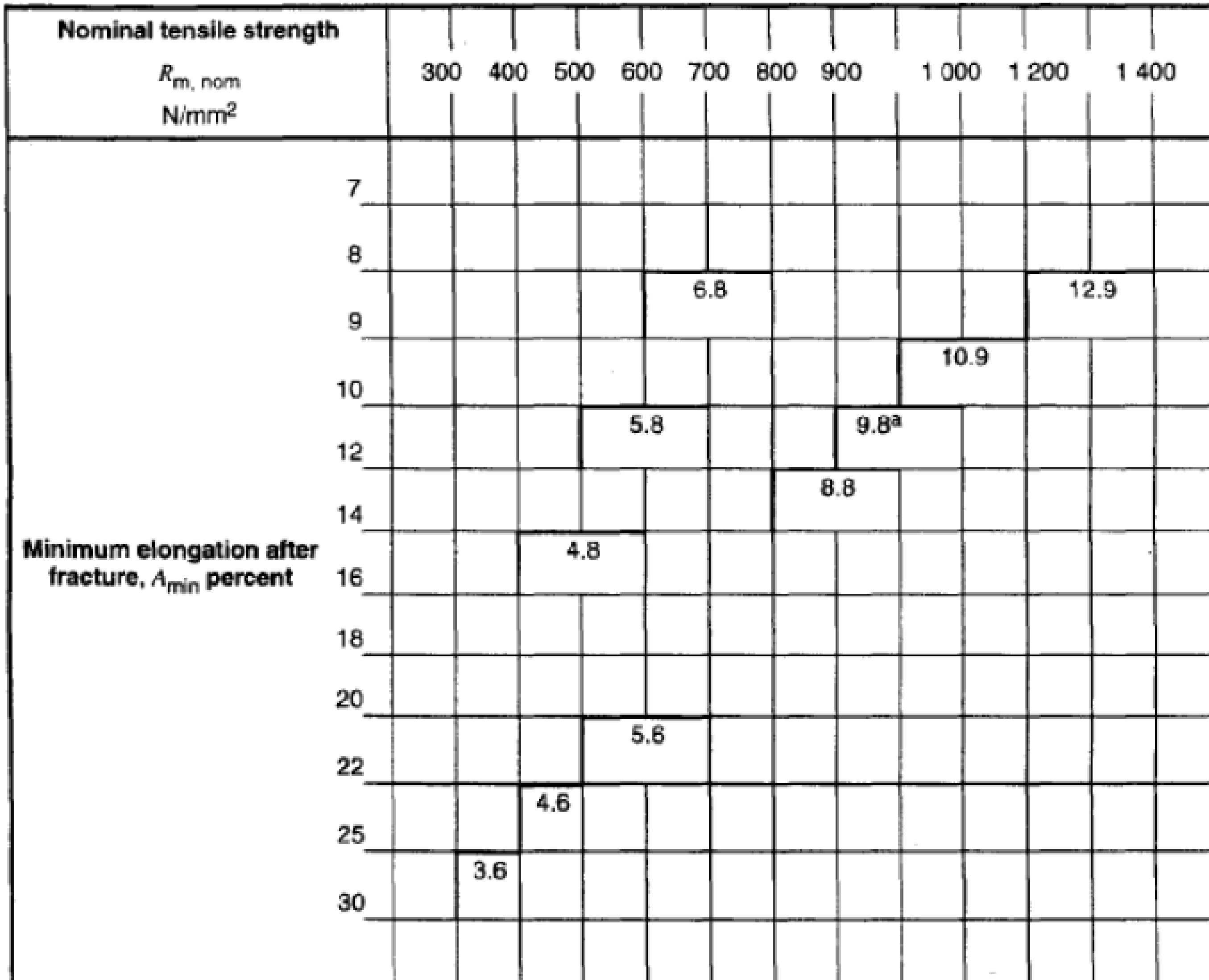
The chemical composition shall be assessed in accordance with the relevant ISO standards.

5 Mechanical and physical properties

When tested by the methods described in clause 8, the bolts, screws and studs shall, at ambient temperature, have the mechanical and physical properties set out in table 3.

Bolt (1)

Table 1 — System of coordinates



Relationship between yield stress and tensile strength			
Second figure of symbol	.6	.8	.9
$\frac{\text{Lower yield stress } R_{eL}{}^{b}}{\text{Nominal tensile strength } R_{m, nom}} \times 100\ \%$ or	60	80	90

Bolt (1)

Table 2 — Steels

Property class	Material and treatment	Chemical composition limits (check analysis) % (m/m)					Tempering temperature
		C		P	S	B [a]	°C
		min.	max.	max.	max.	max.	min.
3.6 [b]	Carbon steel	–	0,20	0,05	0,06	0,003	–
4.6 [b]		–	0,55	0,05	0,06	0,003	–
4.8 [b]							
5.6		0,13	0,55	0,05	0,06		–
5.8 [b]		–	0,55	0,05	0,06	0,003	
6.8 [b]							
8.8 [c]	Carbon steel with additives (e.g. B, Mn or Cr) quenched and tempered	0,15 [d]	0,40	0,035	0,035	0,003	425
	Carbon steel quenched and tempered	0,25	0,55	0,035	0,035		
9.8	Carbon steel with additives (e.g. B, Mn or Cr) quenched and tempered	0,15 [d]	0,35	0,035	0,035	0,003	425
	Carbon steel quenched and tempered	0,25	0,55	0,035	0,035		
<u>10.9</u> [e f]	Carbon steel with additives (e.g. B, Mn or Cr) quenched and tempered	0,15 [d]	0,35	0,035	0,035	0,003	340
10.9 [f]	Carbon steel quenched and tempered	0,25	0,55	0,035	0,035	0,003	425
	Carbon steel with additives (e.g. B, Mn or Cr) quenched and tempered	0,20 [d]	0,55	0,035	0,035		
	Alloy steel quenched and tempered [g]	0,20	0,55	0,035	0,035		
12.9 [f h i]	Alloy steel quenched and tempered [g]	0,28	0,50	0,035	0,035	0,003	380

[a] Boron content can reach 0,005 % provided that non-effective boron is controlled by addition of titanium and/or aluminium.

[b] Free cutting steel is allowed for these property classes with the following maximum sulfur, phosphorus and lead contents: sulfur 0,34 %; phosphorus 0,11 %; lead 0,35 %.

[c] For nominal diameters above 20 mm the steels specified for property classe 10.9 may be necessary in order to achieve sufficient hardenability.

[d] In case of plain carbon boron steel with a carbon content below 0,25 % (ladle analysis), the minimum manganese content shall be 0,6 % for property class 8.8 and 0,7 % for 9.8, 10.9 and <u>10.9</u>.

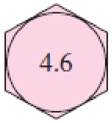
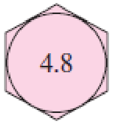
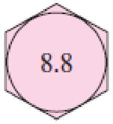
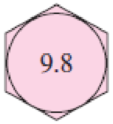
[e] Products shall be additionally identified by underlining the symbol of the property class (see clause 9). All properties of 10.9

Table 3 — Mechanical and physical properties of bolts, screws and studs

Sub-clause number	Mechanical and physical property		Property class 3.6	4.6	4.8	5.6	5.8	6.8	8.8[a] $d \leq 16$[c] mm	8.8[a] $d > 16$[c] mm	9.8[b]	10.9	12.9
5.1	Nominal tensile strength, $R_{m,nom}$	N/mm²	300	400		500		600	800	800	900	1 000	1 200
5.2	Minimum tensile strength, $R_{m,min}$[d,e]	N/mm²	330	400	420	500	520	600	800	830	900	1 040	1 220
5.3	Vickers hardness, HV	min.	95	120	130	155	160	190	250	255	290	320	385
	$F \geq 98$ N	max.	220[f]					250	320	335	360	380	435
5.4	Brinell hardness, HB	min.	90	114	124	147	152	181	238	242	276	304	366
	$F = 30 D^2$	max.	209[f]					238	304	318	342	361	414
5.5	Rockwell hardness, HR	min. HRB	52	67	71	79	82	89	—	—	—	—	—
		min. HRC	—	—	—	—	—	—	22	23	28	32	39
		max. HRB	95,0[f]					99,5	—	—	—	—	—
		max. HRC	—					—	32	34	37	39	44
5.6	Surface hardness, HV 0,3	max.	—						9				
5.7	Lower yield stress R_{eL}[h], N/mm²	nom.	180	240	320	300	400	480	—	—	—	—	—
		min.	190	240	340	300	420	480	—	—	—	—	—
5.8	Stress at 0,2 % non-proportional elongation $R_{p0,2}$[i], N/mm²	nom.	—					—	640	640	720	900	1 080
		min.	—					—	640	660	720	940	1 100
5.9		S_p/R_{eL} or $S_p/R_{p0,2}$	0,94	0,94	0,91	0,93	0,90	0,92	0,91	0,91	0,90	0,88	0,88
	Stress under proof load, S_p	N/mm²	180	225	310	280	380	440	580	600	650	830	970
5.10	Breaking torque, M_B	Nm min.	—						See ISO 898-7				
5.11	Percent elongation after fracture, A	min.	25	22	—	20	—	—	12	12	10	9	8
5.12	Reduction area after fracture, Z	% min.	—						52		48	48	44
5.13	Strength under wedge loading[e]		The values for full size bolts and screws (no studs) shall not be smaller than the minimum values for tensile strength shown in 5.2										
5.14	Impact strength, KU	J min.	—			25	—		30	30	25	20	15
5.15	Head soundness		No fracture										
5.16	Minimum height of non-decarburized thread zone, E		—						$\frac{1}{2} H_1$			$\frac{2}{3} H_1$	$\frac{3}{4} H_1$
	Maximum depth of complete decarburization, G	mm	—						0,015				
5.17	Hardness after retempering		—						Reduction of hardness 20 HV maximum				
5.18	Surface integrity		In accordance with ISO 6157-1 or ISO 6157-3 as appropriate										

Table 8–11

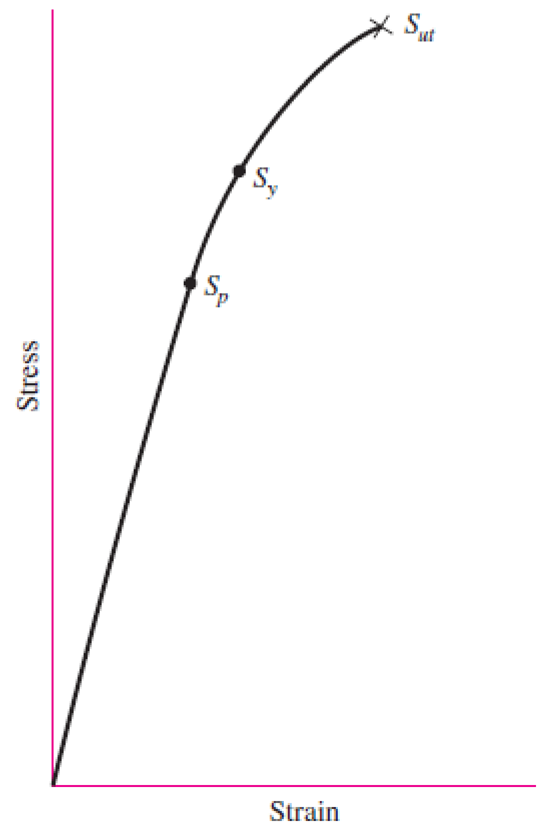
Metric Mechanical-Property Classes for Steel Bolts, Screws, and Studs*

Property Class	Size Range, Inclusive	Minimum Proof Strength,† MPa	Minimum Tensile Strength,† MPa	Minimum Yield Strength,† MPa	Material	Head Marking
4.6	M5–M36	225	400	240	Low or medium carbon	
4.8	M1.6–M16	310	420	340	Low or medium carbon	
5.8	M5–M24	380	520	420	Low or medium carbon	
8.8	M16–M36	600	830	660	Medium carbon, Q&T	
9.8	M1.6–M16	650	900	720	Medium carbon, Q&T	
10.9	M5–M36	830	1040	940	Low-carbon martensite, Q&T	

Bolt(1) – Stress – strain plot

Figure 8–18

Typical stress-strain diagram for bolt materials showing proof strength S_p, yield strength S_y, and ultimate tensile strength S_{ut}.



Bolt(1) - Threads

Table 8–16

Fatigue Stress-Concentration Factors K_f for Threaded Elements

SAE Grade	Metric Grade	Rolled Threads	Cut Threads	Fillet
0 to 2	3.6 to 5.8	2.2	2.8	2.1
4 to 8	6.6 to 10.9	3.0	3.8	2.3

Table 8–17

Fully Corrected Endurance Strengths for Bolts and Screws with Rolled Threads*

Grade or Class	Size Range	Endurance Strength
SAE 5	$\frac{1}{4}$–1 in	18.6 kpsi
	$1\frac{1}{8}$–$1\frac{1}{2}$ in	16.3 kpsi
SAE 7	$\frac{1}{4}$–$1\frac{1}{2}$ in	20.6 kpsi
SAE 8	$\frac{1}{4}$–$1\frac{1}{2}$ in	23.2 kpsi
ISO 8.8	M16–M36	129 MPa
ISO 9.8	M1.6–M16	140 MPa
ISO 10.9	M5–M36	162 MPa
ISO 12.9	M1.6–M36	190 MPa

Bolt :Thread hardness

8.4 Hardness test

For routine inspection, hardness of bolts, screws and studs may be determined on the head, end or shank after removal of any plating or other coating and after suitable preparation of the test piece.

For all property classes, if the maximum hardness is exceeded, a retest shall be conducted at the mid-radius position, one diameter back from the end, at which position the maximum hardness specified shall not be exceeded. In case of doubt, the Vickers hardness test is decisive for acceptance.

Hardness readings for the surface hardness shall be taken on the ends or hexagon flats, which shall be prepared by minimal grinding or polishing to ensure reproducible readings and maintain the original properties of the surface layer of the material. The Vickers test HV 0,3 shall be the referee test for surface hardness testing.

Surface hardness readings taken at HV 0,3 shall be compared with a similar core hardness reading at HV 0,3 in order to make a realistic comparison and determine the relative increase which is permissible up to 30 Vickers points. An increase of more than 30 Vickers points indicates carburization.

For property classes 8.8 to 12.9 the difference between core hardness and surface hardness is decisive for judgeing of the carburization condition in the surface layer of the bolts, screws or studs.

There may not be a direct relationship between hardness and theoretical tensile strength. Maximum hardness values have been selected for reasons other than theoretical maximum strength consideration (e.g. to avoid embrittlement).

NOTE Careful differentiation should be made between an increase in hardness caused by carburization and that due to heat-treatment or cold working of the surface.

Details regards Bolts & Nuts

Bolts	Bolts in fatigue axial loading fail at the fillet under the head, at the thread runout,and at the first thread engaged in the nut.
Nuts	Nuts are graded so that they can be mated with their corresponding grade of bolt. The purpose of the nut is to have its threads deflect to distribute the load of the bolt more evenly to the nut. The nut’s properties are controlled in order to accomplish this. The grade of the nut should be the grade of the bolt
Nut	The material of the nut must be selected carefully to match that of the bolt. During tightening, the first thread of the nut tends to take the entire load; but yielding occurs, with some strengthening due to the cold work that takes place, and the load is eventually divided over about three nut threads. For this reason you should never reuse nuts; in fact, it can be dangerous to do so

Washers

	Flat Washer		Nord-Lock Washer
	Spring Washer		Cup Washer
	Internal Tooth Washer		Contact Washer
	External Tooth Washer		Wave Washer
	Overlap Washer Internal		Curved Washer
	Overlap Washer External		Serrated Locked Washer For Flat Hd Screw
	Two Tongue Washer		Contact Washer with Pilot Point
	Taper Washer		Conical SpringWasher
	Disc Spring Washer		

Indian Standard

FASTENERS — SINGLE COIL RECTANGULAR SECTION SPRING LOCK WASHERS — SPECIFICTAION

(Second Revision)

1 SCOPE

This standard covers requirements for single coil rectangular section spring lock washers suitable for use with bolt/nut assemblies involving fasteners of property class 5·8 or less in the size range 2 to 100 mm.

2 REFERENCES

The following Indian Standards are necessary adjuncts to this standard:

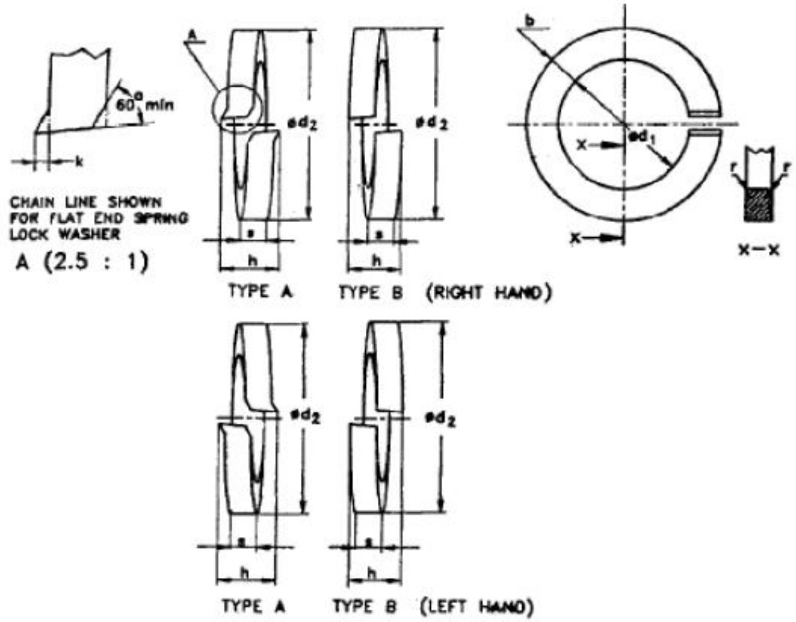
7 FINISH

Spring lock washers shall be supplied in natural finish unless otherwise specified by the purchaser. At the request of the purchaser washers may be phosphate coated, nickel plated, tinned, electrogalvanized, copper plated or cadmium plated. The functional properties of the spring lock washers shall not be impaired as a result of the protective coatings. These coated washers shall be subjected to appropriate treatment as given in the relevant electroplating

Table 1A Dimensions for Spring Washers

(*Clause* 4)

All dimensions in millimetres.



Nom Size	d_1		d_2 *Max*	b		s		r Nom	k*	Weight Approx (7·85 kg/dm³) kg/1 000 pcs	For Bolt, Nut or Screw Size	h			
	Basic	Tol +		Basic	Tol ±	Basic	Tol ±					Type A		Type B	
												Min	*Max*	*Min*	*Max*
2 [1)]	2·1	0·3	4·4	0·9	0·1	0·5	0·1	0·1	—	0·033	2	—	—	1	1·2
2·2 [1) 3)]	2·3	0·3	4·8	1	0·1	0·6	0·1	0·1	—	0·050	2·2	—	—	1·2	1·4
2·5 [1)]	2·6	0·3	5·1	1	0·1	0·6	0·1	0·1	—	0·053	2·5	—	—	1·2	1·4
3 [1)]	3·1	0·3	6·2	1·3	0·1	0·8	0·1	0·2	0·15	0·11	3	1·9	2·1	1·6	1·9
4	4·1	0·3	7·6	1·5	0·1	0·9	0·1	0·2	0·15	0·18	4	2·1	2·5	1·8	2·1
5	5·1	0·3	9·2	1·8	0·1	1·2	0·1	0·2	0·15	0·36	5	2·7	3·2	2·4	2·8
6	6·1	0·4	11·8	2·5	0·15	1·6	0·1	0·3	0·2	0·83	6	3·6	4·2	3·2	3·8
8	8·1	0·4	14·8	3	0·15	2	0·1	0·5	0·3	1·60	8	4·6	5·4	4	4·7
10	10·2	0·5	18·1	3·5	0·2	2·2	0·15	0·5	0·3	2·53	10	5	5·9	4·4	5·2
12	12·2	0·5	21·1	4	0·2	2·5	0·15	1·0	0·4	3·82	12	5·8	6·8	5	5·9
16	16·2	0·8	27·4	5	0·2	3·5	0·2	1·0	0·4	8·91	16	7·8	9·2	7	8·3

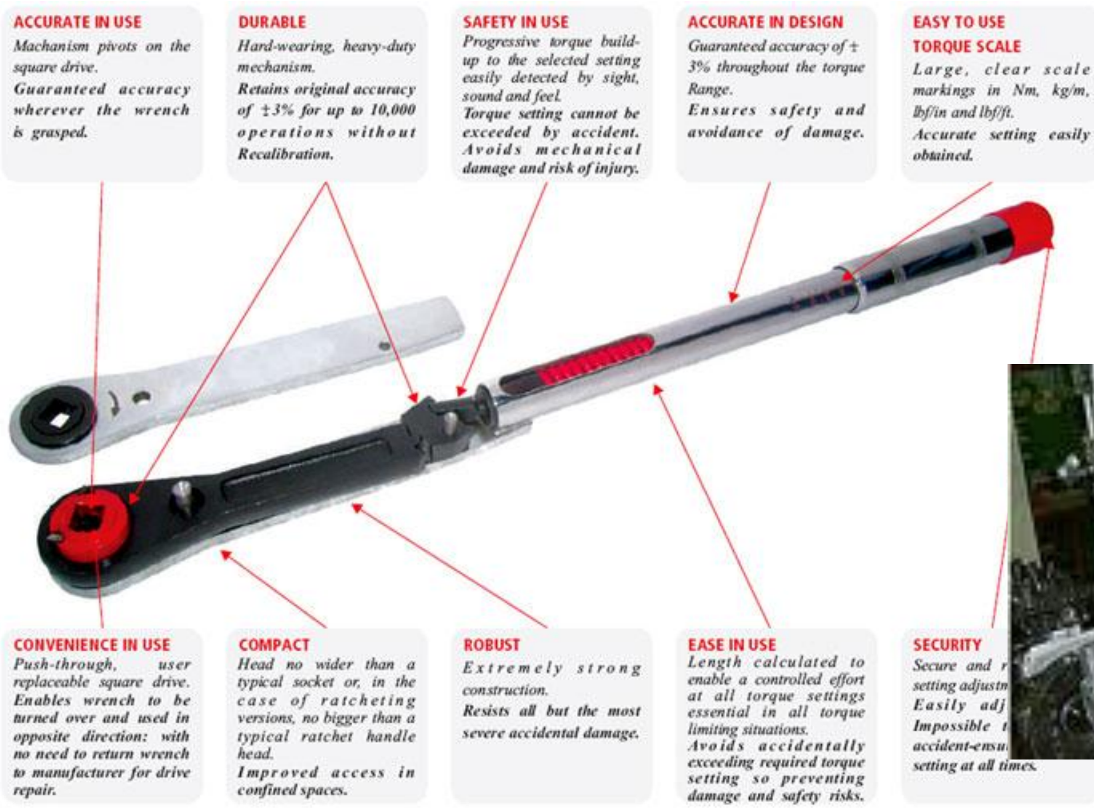
Thread Locking Options

Members

Members	There may be more than two members included in the grip of the fastener. All together these act like compressive springs in series, and hence the total spring rate of the members is $1/k_m = 1/k_1 + 1/k_2 + 1/k_3 + \cdot\cdot\cdot + 1/k_i$ If one of the members is a soft gasket, its stiffness relative to the other members is usually so small that for all practical purposes the others can be neglected and only the gasket stiffness used.

Spanners

Torque wrenches and Nut runners



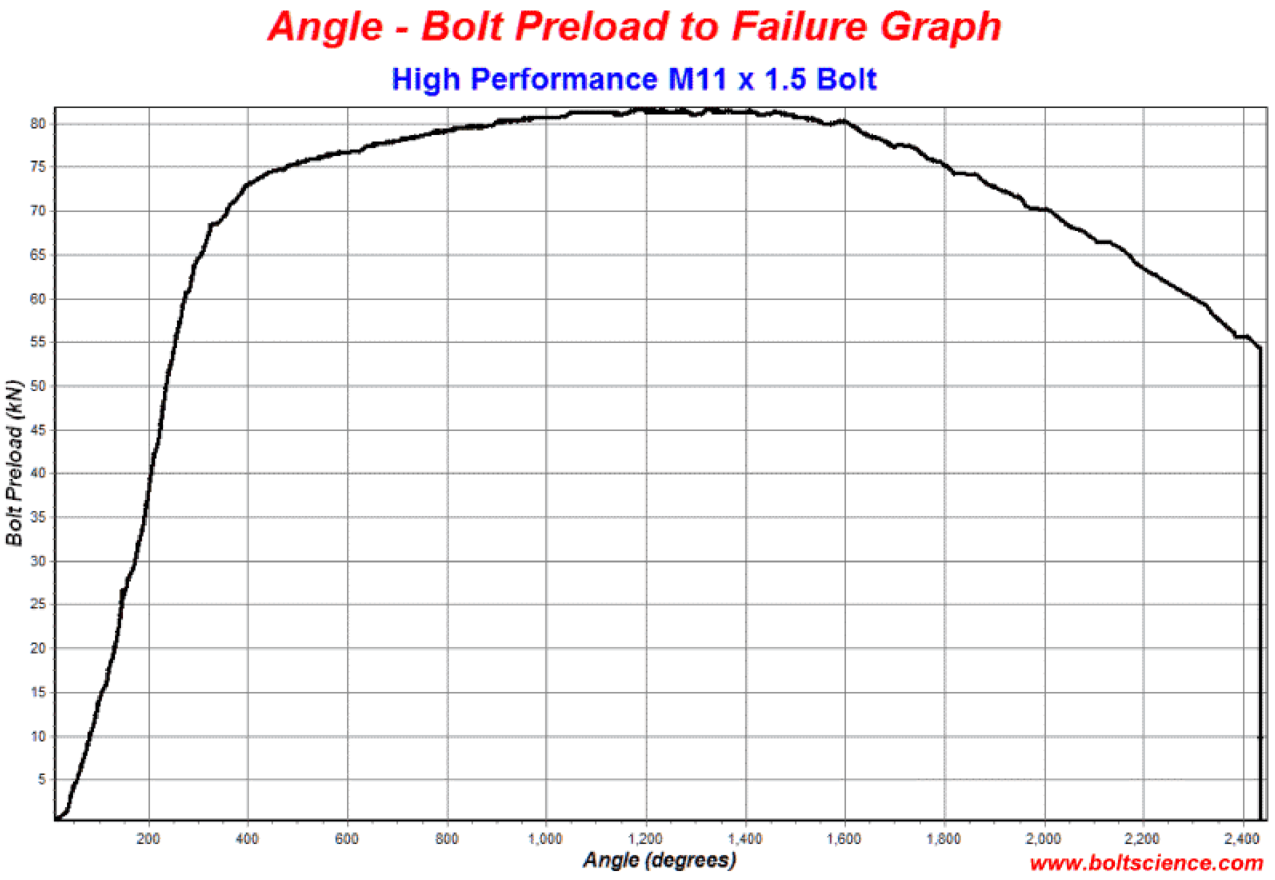
Assembly Basics

Bolt	The ideal bolt length is one in which only one or two threads project from the nut after it is tightened.
Assembly	• The purpose of a bolt is to clamp two or more parts together. • The clamping load is obtained by twisting the nut until the bolt has elongated almost to the elastic limit. This clamping force is called the pretension or bolt preload. It exists in the connection after the nut has been properly tightened no matter whether the external tensile load P is exerted or not. Of course, since the members are being clamped together, the clamping force that produces tension in the bolt induces compression in the members.

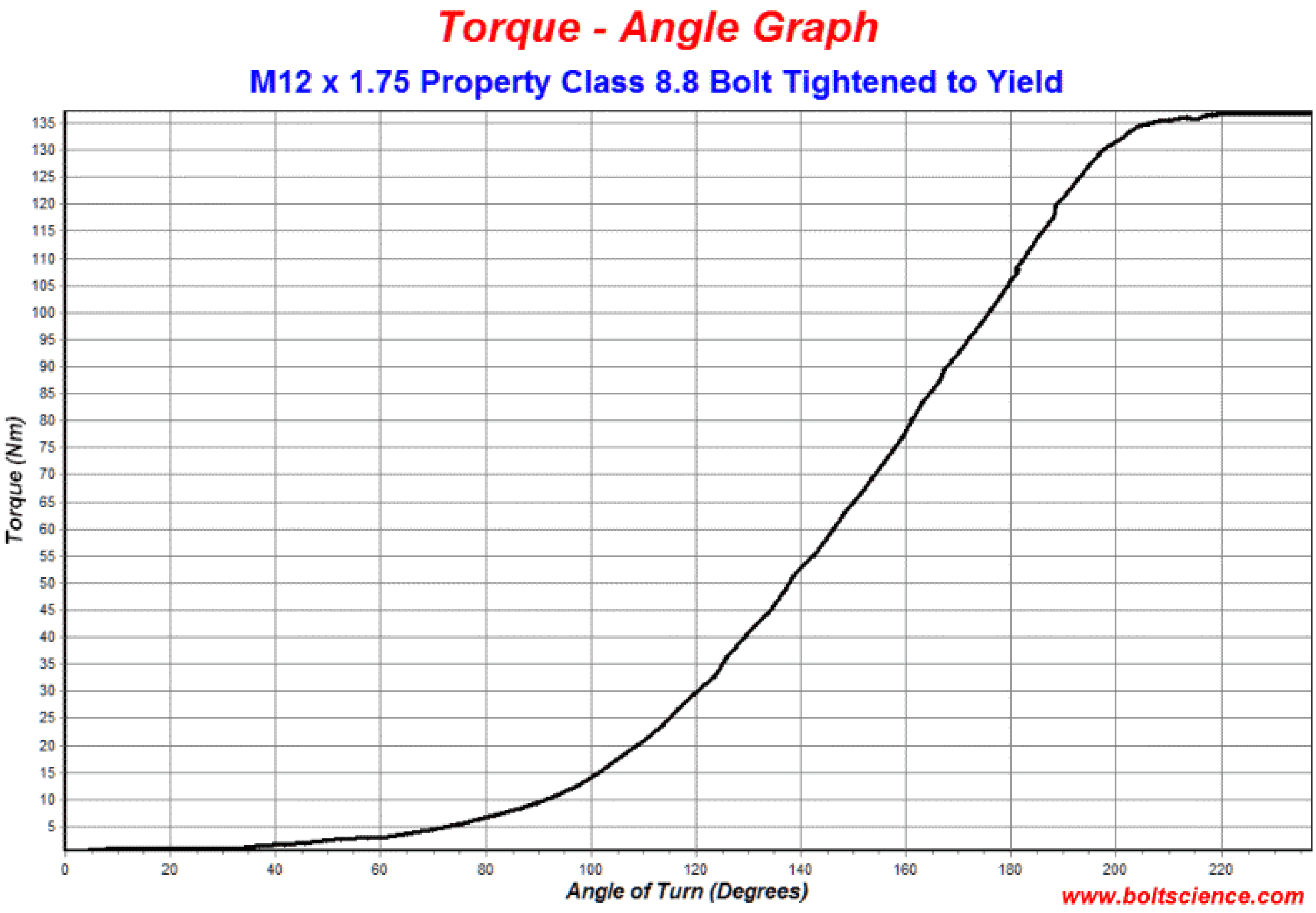
Tightening

Assembly	The elongation of a screw cannot usually be measured in many cases In such cases the wrench torque required to develop the specified preload must be estimated.
Torqueing methods	Then torque wrenching, pneumatic/impact wrenching, or the turn-of-the-nut method may be used.
Torque wrench	The torque wrench has a built-in dial that indicates the proper torque. With impact wrenching, the air pressure is adjusted so that the wrench stalls when the proper torque is obtained, or in some wrenches, the air automatically shuts off at the desired torque.
Angle tightening	The turn-of-the-nut method requires that we first define the torque for snug-tight. The turn-of-the-nut method requires that you compute the fractional number of turns necessary to develop the required preload from the snug-tight condition.

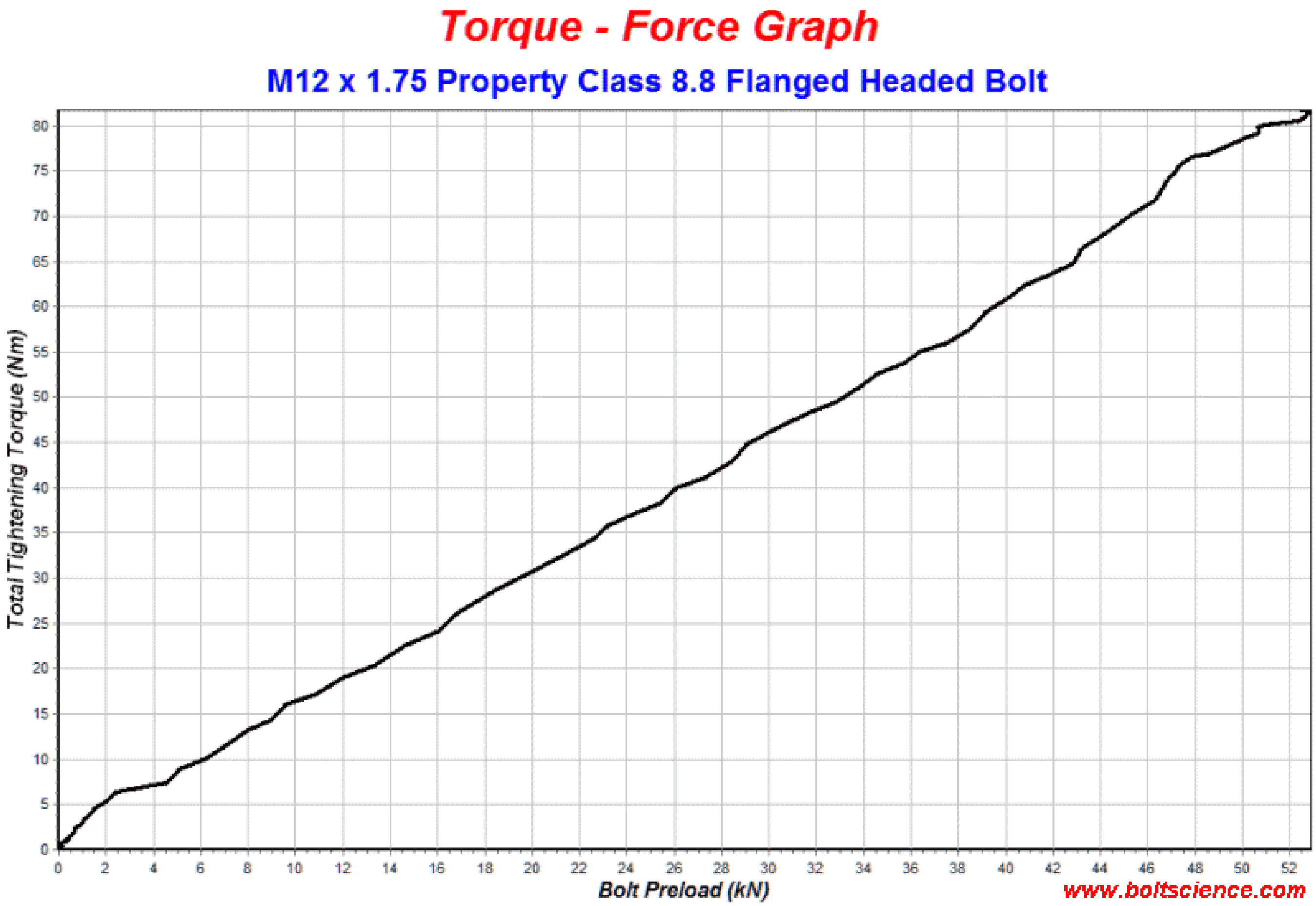
Turn of Nut method



Turn of nut method



Torqueing method



Torqueing

	Equation (c) can now be written T = K .Fi.d .....[T :Nm / Fi: KN/ d:mm] The coefficient of friction depends upon the surface smoothness, accuracy, and degree of lubrication.

Table 8–15

Torque Factors K for Use with Eq. (8–27)

Bolt Condition	K
Nonplated, black finish	0.30
Zinc-plated	0.20
Lubricated	0.18
Cadmium-plated	0.16
With Bowman Anti-Seize	0.12
With Bowman-Grip nuts	0.09

Table 8–14

Distribution of Preload F_i for 10 Tests of Lubricated Bolts Torqued to 90 N · m

30.3,	32.5,	32.5,	32.9,	32.9,	33.8,	34.3,	34.7,	37.4,	40.5

*Mean value, $\bar{F}_i = 34.18$ kN. Standard deviation, $\hat{\sigma} = 2.88$ kN.

Summary

	Materials for automobiles cover a wide range of materials. While special applications like race cars will utilize state of art materials, materials used in mass produced automobiles are conventional and selection in addition to the properties required is based on factors like cost, availability, ease of manufacture, environmental impact and safety.
	Materials supply condition specifications will depend on whether materials are further processed – machined / heat or surface treated, or whether they are used without processing.
	An example of the bolted joint is discussed to evaluate the details required and the approach to materials selection.