Bolt Grades

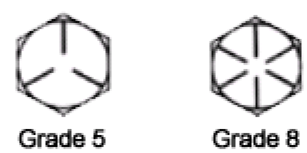
I have been on a quite a few online email lists over the last 7 years or so, basically since they first came out. From the original Jeep-L list to the XJ-list to the Rockcrawler.com board, a common question comes up time and time again. No, I'm not talking about "how big a tire can I fit" or "which tire is better." I'll save those questions for the opinion section of everyone else's website. I'm referring to the age-old question of "which fastener grade should I use?"

It seems that everyone has an opinion on which grade is better but not many people can or will tell you why. Well, I'd like to explain the technical difference between a SAE Grade 8 (Grade 8) and a SAE Grade 5 (Grade 5) fastener.

Most people think a bolt is a bolt is a bolt. They see it as a machined chunk of metal that holds or attaches things. Fasteners (aka bolts or screws) are complex mechanically-engineered hardware. They are made using different materials, different thread types (i.e. coarse, fine, extra fine), various lengths, with grip or no grip (shank), different types (i.e. hex, 12 pt, carriage, etc.), different coatings (i.e. passivated, cadmium, dry film lube, etc.), various classes of fit (i.e. class 3), and multiple grades (i.e. grade 5, 8, etc.).

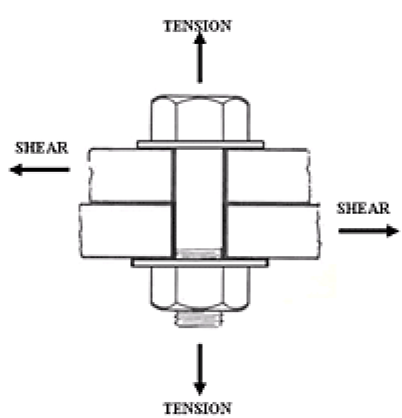
Bolts come with left or right hand threads, metric or SAE threads, different number of threads per inch (i.e. 20 or 28 for the same size fastener) and various versions of those (i.e. UNF versus UNJF). In addition, there are way too many military specs in existence to list them all here. So with all these differences, it's no wonder most people don't understand the difference between fasteners very well. Of all these differences, I'll focus on the different grades since that is what most shade tree mechanics ask about.

First, you need to be able to identify bolts by the different grades when you go to the local hardware store. Grade 5 bolts have 3 marks or lines on the head that are in the shape of a "Y". Grade 8 bolts have 6 marks on the head.



Second, the different grades have a meaning to them. It tells you how strong the fastener is. There are different types of strengths listed for each grade. Proof strength (about 90% of yield), ultimate tensile strength (bolt fails in stretch), yield strength (bolt begins to get a permanent set and changes cross-sectional area typically) and shear strength (bolt prevents parts from separating by using it's shank or body as a stop).

Depending on how you are using the fastener, you would look at the appropriate and corresponding strength type. For example, bolts that attach a D-ring bracket to the bumper face of a vehicle would be critical in tension . So you would want to know what the tensile strength a particular bolt is. Bolts that attach winch-mounting plates are typically seeing mostly shear loads thus preventing the winch from departing from the vehicle during winching operations. In that case, shear strength is important to you.



Mark's Standard Handbook for Mechanical Engineers lists Grade 5 fasteners as 120 ksi fasteners. This means the tensile strength is 120,000 lbs per square inch. It also lists Grade 8's as 150 ksi fasteners meaning the tensile strength is 150,000 lbs per square inch. Also, the ultimate shear strength of a fastener is typically about 60% of its ultimate tension strength. So given a certain diameter (cross-sectional area) and strength rating, someone can figure out how much load that fastener can carry in both tension and shear.

Example of bolts under single shear load

Example of bolts under tension

Let’s look at an example of where grade 5 and grade 8 bolts are subjected to single shear loads (winch plate reference).

Using a .250-inch diameter grade 8 fastener gives you the following shear capability:

A = Cross-sectional area of the fastener size (since bolt bodies/shanks have circular cross-sections, use area of a circle) = Pi x r2 where R (radius) = .250/2 = .125, therefore A = Pi x (.125)2 = .0491 square inches (in2)

Capability in shear *= 91,000 lbs / in2 x .0491 in2 =* ***4468 lbs***

Using the same .250-inch diameter grade 5 fastener results in the following:

Capability in shear *= 75,000 lbs / in2 x .0491 in2 =* ***3683 lbs***

That’s a difference of over 750 lbs or over 1/3 ton. In this example you can clearly see that using a grade 8 fastener has a superior advantage over the grade 5. Therefore the result is if someone is using grade 5 bolts in a shear application like the winch plate example, they will fail almost 800 lbs earlier.

I’ve also heard the argument that grade 8’s are more brittle than grade 5’s and that’s why you shouldn’t use them. Well, first you need to understand what the term “*brittle*” really means. Brittleness in bolts is defined as failure at stresses apparently below the strength of the bolt material with little or no evidence of plastic deformation. Typically, fasteners are not brittle below 180 ksi ultimate tensile strength. Grade 5’s have an ultimate tensile strength of 120 ksi and a grade 8 fastener has an ultimate tensile strength of 150 ksi. This is why brittle is a relative term. Nearly all fasteners are considered ductile except some made from PH 15-6 Mo, 17-4 PH and 17-7 PH.

Going back to the D-ring on the face of the bumper example, you would want to know its tensile carrying capability. Calculating the tensile capability is not as easy as shear since the thinnest portion of the bolt is at the minor diameter of the threads (bottom of the thread “V”). So you need to know the nominal minor diameter of that particular fastener. That’s where military specification MIL-S-8879C comes in. It is titled “*Screw threads, controlled radius root with increased minor diameter, general specification for*”. It lists that and a lot more for almost all possible fasteners. MIL-S-8879C lists the nominal minor diameter of a .2500-28-UNF at .2065 inches. We can now calculate the A (area) of the cross-section:

A = Pi x r2 = Pi x (.2065/2)2 = .03349 in2

Grade 8 bolt capability in yield (stretch) = 130,000 lbs / in2 x .03349 in2 = **4354 lbs minimum**

Grade 8 bolt capability in tension (failure) = 150,000 lbs / in2 x .03349 in2 = **5024 lbs minimum**

Grade 5 bolt capability in yield (stretch) = 92,000 lbs / in2 x .03349 in2 = **3081 lbs minimum**

Grade 5 bolt capability in tension (failure) = 120,000 lbs / in2 x .03349 in2 = **4019 lbs minimum**

Again, you can see that the grade 8 will support over 1000 lbs more or a 1/2-ton more. But there's something more important to note. The grade 5 fastener has already reached its ultimate load and FAILED BEFORE the grade 8 starts to yield or stretch. Therefore, the argument that you should not use grade 8's because they are more brittle than grade 5's is not a true statement in most applications.

Toughness is an important feature of a fastener. It is the opposite of brittleness and gives you an idea of how it will handle abuse without being damaged and eventually weakening the fastener or can cause fatigue to appear much earlier than normal. One way to "measure" toughness is by looking at the hardness rating of a fastener. The higher the number (Brinell, Rockwell …) the harder the material is and the tougher it is to damage. According to *Marks' Standard Handbook for Mechanical Engineers*, Grade 5's typically have a core Rockwell hardness of C25-C34 whereas a grade 8 typically has a core Rockwell hardness of C33-C39. Based on this, grade 8's are tougher than grade 5's.

Fatigue usually doesn't play a big part in grade 8 or grade 5 fasteners since most steels are good for 2 million to 10 million cycles. Far more than you will ever winch or pull on. Here is a quick point about fastener fatigue. Almost all fastener fatigue failures are the result of improper (almost always too low) torque. Too low a torque will cause the fastener to pick up more load more often and eventually cycle it to failure. Therefore, you want to make sure you torque your fasteners to the appropriate level using a torque wrench and make sure to torque dry, clean threads. Lubricated threads significantly change the actual preload on the fastener and you risk over torquing it.

Due to space and time limitations, here is a chart showing you the tension and shear minimum capabilities of different grade fasteners relative to their size.

			SAE Grade 5	SAE Grade 8	ARP Fastener	SPS Fastener	MS14181	SPS Fastener
Ultimate Tensile Capability of Fastener (ksi)			120	150	160	180	220	260
Ultimate Shear Capability of Fastener (ksi)			75	91	95	108	132	156
Fastener Diameter		Typical Material	Med Carbon Steel	Med Carbon Alloy Steel	A286 CRES	A286 CRES	Inconel 718	MP35N Super Alloy
in.	thrds/in							
0.1640	32	Tension Capability (lb)	1468	1835	1957	2202	2691	3181
		Shear Capability (lb)	1584	1922	2007	2281	2788	3295
0.1900	32	Tension Capability (lb)	2169	2711	2892	3253	3976	4699
		Shear Capability (lb)	2126	2580	2694	3062	3743	4420
0.2500	28	Tension Capability (lb)	4007	5009	5340	6010	7347	8682
		Shear Capability (lb)	3682	4470	4660	5300	6480	7660
0.3125	24	Tension Capability (lb)	6440	8050	8590	9660	11807	13953
		Shear Capability (lb)	5750	6980	7290	8280	10120	11970
0.3750	24	Tension Capability (lb)	9888	12360	13180	14830	18127	21423

		Shear Capability (lb)	8280	10050	10490	11930	14580	17230
0.4375	20	Tension Capability (lb)	13338	16673	17780	20010	24453	28899
		Shear Capability (lb)	11270	13680	14280	16240	19840	23450
0.5000	20	Tension Capability (lb)	18139	22674	24190	27210	33255	39302
		Shear Capability (lb)	14730	17870	18650	21210	25920	30770
0.5625	18	Tension Capability (lb)	23028	28785	30700	34540	42218	49894
		Shear Capability (lb)	18640	22610	23610	26840	32800	38770
0.6250	18	Tension Capability (lb)	29218	36524	38960	43800	53568	63307
		Shear Capability (lb)	23010	27920	29150	33130	40500	47900
0.7500	16	Tension Capability (lb)	42726	53408	57000	64100	78331	92573
		Shear Capability (lb)	33130	40200	42000	47700	58300	68900
0.8750	14	Tension Capability (lb)	58434	73043	77900	87700	107129	126607
		Shear Capability (lb)	45100	54700	57100	64900	79400	93800
1.0000	12	Tension Capability (lb)	75968	94961	101300	114000	139275	164598
		Shear Capability (lb)	58900	71500	74600	84800	103700	122500

These examples show how much of a load can be carried by the fastener BUT you need to make sure the parent material is strong enough to handle the loads, as well, otherwise it will fail. Industry practice is to apply a safety factor to address any unknowns and/or combined load cases to give you an adequate margin of safety.

Another good point to make is to never reuse fasteners after they have been subjected to loading or the elements. Corrosion can cause a fastener to fail well below its initial strength. So be smart and use only new fasteners when installing or reinstalling some cool new widget on your rig.

Getting back to the original question, "*which fastener grade should I use?*" I hope it's very clear by now that grade 8 fasteners are far superior to grade 5 fasteners. If this is so, then why do the automotive manufacturers use some grade 5 fasteners? The automotive OEM's use what it needs to be safe and nothing more since there is a difference in cost between grade 5 and grade 8 (or metric 8.8 and 10.9). Since the OEM's manufacture millions of vehicles each year, the difference in a few cents per fastener adds up to a lot for them. However, as an individual who has spent some serious coin on a winch or lift kit, I wouldn't let the few cents difference in the cost of a grade 8 versus a grade 5 fastener make up my mind as to which fastener I would use.

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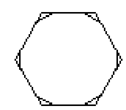
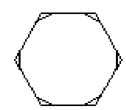
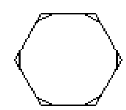
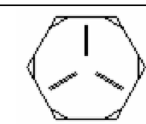
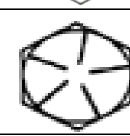
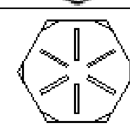
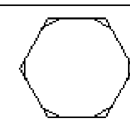
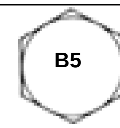
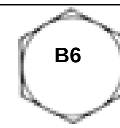
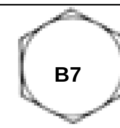
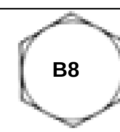
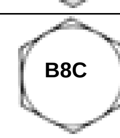
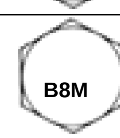
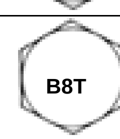
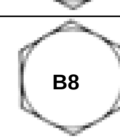
Bolt Grade and Quality Cross Reference

KLINGER EXPERT®

Standard	Grade or Class	KLINGER® expert Alternative	Material	Nominal Product Diameters (Inches)	Minimum Yield Strength (psi)	Minimum Tensile Strength (psi)	Identification
SAE J429	Grade 1	4.6	Low Carbon Steel	0.25 - 1.5	36000	60000	
	Grade 2	5.8	Low Carbon Steel	.25 - .75	57000	74000	
		4.6		>0.75 - 1.5	36000	60000	
	Grade 4	8.8	Medium Carbon Steel	0.25 - 1.5	100000	115000	
	Grade 5	8.8	Medium Carbon Steel	0.25 - 1	92000	120000	
		6.9		>1 - 1.5	81000	105000	
	Grade 5.1	B80	Medium Carbon Steel	0.25 - 1.0	87000	120000	
	Grade 7	B7	Medium Carbon Steel	0.25 - 1.5	115000	133000	
	Grade 8	10.9	Medium Carbon Steel	0.25 - 1.5	130000	150000	
	Grade 8.1	10.9	Medium Carbon Steel	0.25 - 1.5	130000	150000	

Standard	Grade or Class	KLINGER® expert Alternative	Material	Nominal Product Diameters (Inches)	Minimum Yield Strength (psi)	Minimum Tensile Strength (psi)	Identification
ASTM A325	Type 1	B80	Medium Carbon Steel	0.5 - 1	85000	120000	
		6.8		>1 - 1.5	74000	105000	
	Type 2	B80	Low Carbon Steel	0.5 - 1	85000	120000	
		6.8		>1 - 1.5	74000	105000	
	Type 3	B80	Atmopheric Corrosion Resistance Steel	0.5 - 1	85000	120000	
		6.8		>1 - 1.5	74000	105000	
ASTM A193	Grade B5	6.9	AISI 501	0.25 - 4	80000	100000	
	Grade B6	B80	AISI 410	0.25 - 4	85000	110000	
	Grade B7	B7	AISI 4140, 4142, or 4105	.025 - 2.5	105000	125000	
				>2.5 - 4	95000	115000	
				>4 - 7	75000	100000	
	Grade B16	B16	CrMoVa Alloy Steel	.025 - 2.5	105000	125000	
				>2.5 - 4	95000	115000	
				>4 - 7	85000	100000	
	Grade B8	B8	AISI 304	0.25 & up	30000	75000	
	Grade B8C	B8	AISI 347	0.25 & up	30000	75000	
	Grade B8M	B8	AISI 316	0.25 & up	30000	75000	
	Grade B8T	B8	AISI 321	0.25 & up	30000	75000	
	Grade B8	B8X	AISI 304 Strain Hardened	0.25 - 0.75	100000	125000	
				>0.75 - 1	80000	11500	
				>1 – 1.25	65000	105000	
				>1.25 – 1.5	50000	100000	

Standard	Grade or Class	KLINGER® expert Alternative	Material	Nominal Product Diameters (Inches)	Minimum Yield Strength (psi)	Minimum Tensile Strength (psi)	Identification
ASTM A193	Grade B8C	B8X	AISI 347 Strain Hardened	0.25 - 0.75	100000	125000	B8C
ASTM A193	Grade B8C	B8X	AISI 347 Strain Hardened	>0.75 - 1	80000	115000	B8C
ASTM A193	Grade B8C	B8X	AISI 347 Strain Hardened	>1 - 1.25	65000	105000	B8C
ASTM A193	Grade B8C	B8X	AISI 347 Strain Hardened	>1.25 - 1.5	50000	100000	B8C
ASTM A193	Grade B8M	B80A	AISI 316 Strain Hardened	0.25 - 0.75	95000	110000	B8M
ASTM A193	Grade B8M	B80A	AISI 316 Strain Hardened	>0.75 - 1	80000	100000	B8M
ASTM A193	Grade B8M	B80A	AISI 316 Strain Hardened	>1 - 1.25	65000	95000	B8M
ASTM A193	Grade B8M	B80A	AISI 316 Strain Hardened	>1.25 - 1.5	50000	90000	B8M
ASTM A193	Grade B8T	B8X	AISI 321 Strain Hardened	0.25 - 0.75	100000	125000	B8T
ASTM A193	Grade B8T	B8X	AISI 321 Strain Hardened	>0.75 - 1	80000	115000	B8T
ASTM A193	Grade B8T	B8X	AISI 321 Strain Hardened	>1 - 1.25	65000	105000	B8T
ASTM A193	Grade B8T	B8X	AISI 321 Strain Hardened	>1.25 - 1.5	50000	100000	B8T
ASTM 307	Grade A or B	4.6	Low Carbon Steel	0.25 - 1.5	36000	60000	
ISO R898	Class 4.6	4.6	Medium Carbon Steel	All Sizes Thru 1.5	36000	60000	
ISO R898	Class 5.8	5.8	Medium Carbon Steel	All Sizes Thru 1.5	57000	74000	
ISO R898	Class 8.8	8.8	Alloy Steel	All Sizes Thru 1.5	92000	120000	8.8
ISO R898	Class 10.9	10.9	Alloy Steel	All Sizes Thru 1.5	130000	150000	10.9
ISO R898	Class 12.9	12.9	Alloy Steel	All Sizes Thru 1.5	160000	177000	12.9

Note: This cross reference is based on yield strengths and is for reference only. It is intended to help the user determine the nearest bolt/stud grade equivalent when what is employed is not found in KLINGER Expert®. Bolt grades and/or qualities may not be exactly equivalent but should provide a comparable bolt that can be used in the KLINGER Expert® program. In future versions of KLINGER Expert®, a larger selection of UNC bolt grades may be added make this cross reference obsolete.