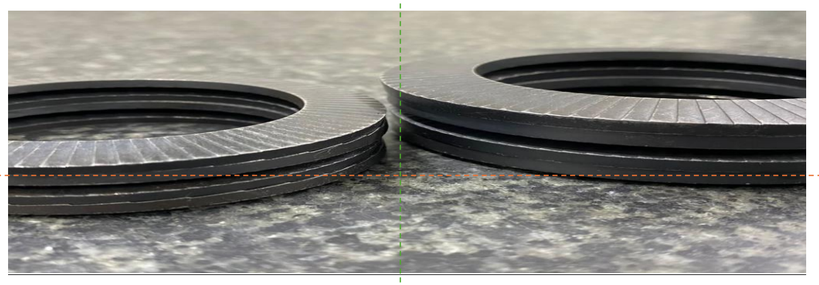
HOW TO USE CONICAL WEDGE LOCK WASHER PAIRS

Introduction

The Conical Wedge Lock washers contained in this package are to be used in pairs. They are manufactured from Spring Steel, hardened to Rockwell C of 46 to 48, with a Black Oxidization surface treatment which provides both anti-corrosion properties and reduced friction, reducing Torque, when properly lubricated. They have 3 distinct physical features:

1. They are shaped in a dome, so that a force must be applied to flatten them, just like a spring.
2. Each has a mating surface with wedge shaped CAMS into which the other locks.
3. The outer surface has smaller radial GRIPS that will embed themselves into the respective assembly surface.

These physical properties are specifically designed to prevent loosening of any static bolted connection they are applied to, and deals with both **spontaneous** loosening and **non-rotational** loosening.

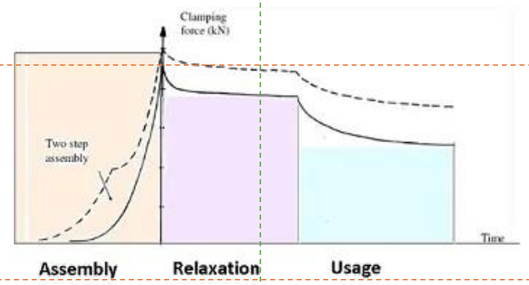


Spontaneous loosening of a bolted assembly takes place when the fastened bolt/nut rotates "spontaneously", and often the slightest rotation of only a few degrees is sufficient for a bolted connection **to lose all its preload**.

This rotational loosening is exacerbated when any part of the bolted assembly experiences slackening. This is a collective term for the various causes **of non-rotational loosening**.

The Conical Wedge Lock Washer Pair contained in this packet address both the rotational and non-rotational causes for loss of preload in a well-designed bolted connection, firstly (as the Safety Washer does) using CAM geometry and contact GRIPS to deal with spontaneous bolt loosening **from shocks, vibrations, and dynamic loading** and secondly, (which is where our improvement focuses) it addresses slackening due to **settlement, creep, differential thermal expansion, relaxation and yielding**.

Settlement (also called Embedding) takes place on the contact surfaces between the various assembly parts and is easily observed by indentations. It is caused by localised plastic deformation. Surfaces may appear to be smooth but when sufficiently magnified, jagged peaks are evident (these are the same structures that Shot Peening targets as they are also the source of fatigue crack propagation). They are called asperities.



A drop of preload directly following the tightening procedure is mainly attributed **to settlement and elastic recovery**. Unlike with settlement or creep, the **clamp length does not change**, which makes it more difficult to detect. Subsequent loss of preload follows a power function with time. Retightening of bolts can reduce the preload loss due to relaxation, but the preload loss directly following the tightening procedure prevails, especially when tightening is done at a fast rate.

The actual contact area between opposing asperities can be substantially less than the apparent area. It is these asperity contacts that deform and flatten. The loading to cause this is substantially less than the load needed to plastically deform the entire apparent contact area. **Stress-Relaxation is the decrease of preload, experienced over time, with no visible physical change to the bolt**. This is a form of creep and occurs when high stresses present in a bolt are relieved over time, most notably, at elevated temperatures.

Creep (sometimes called cold flow) is a property of materials that results in **progressive deformation** and is a result of long-term exposure **to high levels of stress** that are still below the yield strength of the material. Creep is more severe in materials that are subjected to heat for long periods and generally increases as they near their melting point. The rate of creep deformation is a function of the material's inherent mechanical properties, exposure time, exposure temperature and the applied load.

When **slackening occurs** for any reason, the typical wedge geometry will NOT maintain preload and keep the connection secure. This is why we have taken our years of experience in **Conical Disc Spring design** and manufacture and applied these insights to the issue of slackening as a cause of preload loss. A good understanding and control of the torque vs clamp load relationship is essential to minimise the probability of loss of preload as we must firstly work within the mechanical constraints and realities of the assembly.

Conditions arise frequently where these phenomena that cause slackening materialise, here ae a few examples:

1) Whenever a gasket or similar seal is part of the assembly.
2) Where the clamp load has a Powder Coating or thick Paint surface protection finish
3) Where the clamping is made up of multiple components
4) Where clamped parts are softer metals, or polymers
5) The assembly is subjected to thermal differentials and expands and contracts
6) Where lower property class bolts of 4.6, 8.6 are used, instead of 8.8, 10.9 and 12.9
7) Where field conditions are beyond the control of operations and installation lacks discipline.

In all these scenarios, the geometry of the CAM alone will be insufficient to prevent loosening, and the extra Spring effect, provided by the Conical Shape is required to further reduce the likelihood of preload being lost.

The Evolution of the Conical Wedge Lock Washer

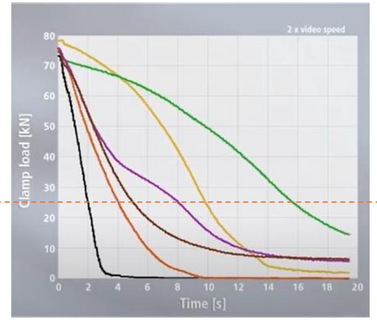
We have explained the sources and cause of slackening in a static bolted connection and why, when slackening occurs for any reason, the typical wedge geometry will not maintain preload and keep the connection secure. This is why we have taken our years of experience in Conical Disc Spring design and manufacture and applied these insights to the issue of slackening as a cause of preload loss.

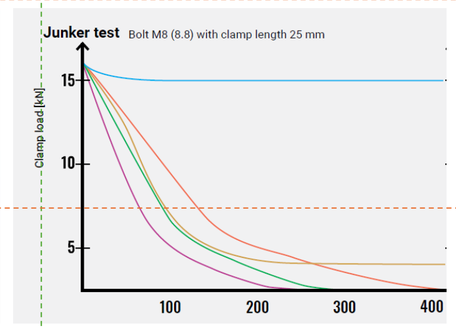
When we combine the Nordloc Safety Washer's Geometry with a Conical Disc Spring

When the fasener is tightened the CAMS lock and he GRIPS on the outer surfaces embed themselves into the fastener nut and the clamped part, leaving impressions on both. Because the gradient of of the wedges is greaer than the size of the fasteners pitch, any rotational movement results in tightening of the wedges and an increase in preload, thus securing the assembly.

Comparative Junker Tests

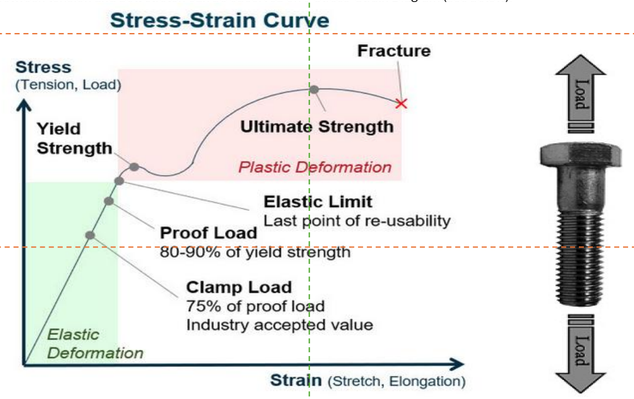
What typically happens when different solutions are applied to a bolted connection? Without exception, whether a nut and washer, spring washer, double nut, Nylon insert, Helical Spring washer, preload is lost spontaneously.





The Stress-Strain Curve

The relationship between tension and bolt stretch can be observed on a Stress-Strain Diagram (see below).



Most parts of a bolted assembly operate within the elastic region and revert to shape after the load is released, but this is only if the induced stresses **have not exceeded the underlying material's yield strength**. A bolt assembly that is properly tensioned should be working in the elastic range (in green), if the load applied causes the fastener to exceed its yield point, it enters the plastic deformation range (in pink).

Bolts have a **defined Proof Load** which is an applied tensile load that the fastener must support without permanent deformation. The Yield Point is the point at which permanent deformation begins. At this point, the metal is no longer able to return to its original shape if the load is removed. Continuing with the application of more load, gets us to the maximum stress load. Beyond this point the fastener continues to "neck" and elongate further, with a reduction in stress.

We have used the ISO 898-1 standard for the calculations we provide on the various class of bolt most commonly used in bolted connections. We use **a Clamp Load that is 75% - 80% of the defined Proof Load**, and we will show you how to verify whether any combination of applied torque and preload for any particular class of bolt falls within the mechanical limits that the standard sets. Everything revolves around how much stress a load will induce in the bolt, and what deformation of the bolt can be tolerated.

Understanding the effect of k-factor

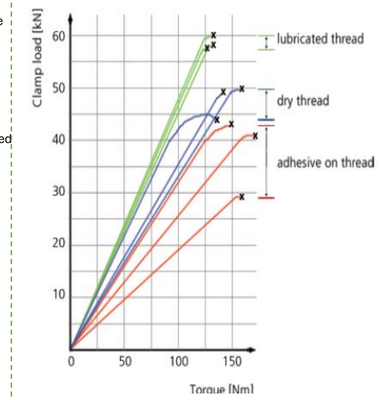
The best way to think of the K_{est} / Nut Factor is as a **measure of as anything that increases or decreases the friction** within the bolted assembly and the threads of the nut. There are three contribution factors:

1) the friction between the threads of the bolt and the threads of the nut – called the Thread Friction - μ_{th} or μ_s (s as in shank)

2) the friction of the nut against the surface against which it rotates and bonds – called the under-head friction, - μ_h or μ_w and

3) friction causes by variations in geometry and the profile of the threads – geometric friction – sometimes frictional drag associated with the thread locking adhesive is included here

   This 3rd contribution is only generally only apparent when the thread is damaged (nicked) or intentionally through design



We calculate what Torque must be applied to a bolted connection using:

$$T = K \times d \times F$$

Where:
d = the nominal diameter of the bolt thread
F = the Load that must be generated from applying the Torque, and
K = the Nut Factor (also called the K factor, torque coefficient, friction factor)

Fortunately, the K-Factor can be looked up in tables that have been empirically worked out for you. But as a rule of thumb, you can use the following estimations, where the Bolt Condition is:

- Non-plated and dry – K = 0.2 to 0.3
- Zinc-plated and clean. But dry – K = 0.17 to 0.22
- Black Oxided and lubricated– K = 0.13 to 0.18
- Properly lubricated – K = 0.10 to 0.14

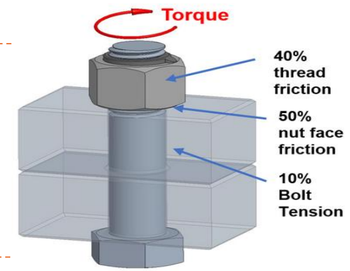
Bolt and Nut Coarse Screw Threads
JIS B 0205 (ISO 724) thread standard

Between Threads, μ_s	Coefficient of Friction K: Between Bearing Surfaces, μ_w									
	0.08	0.10	0.12	0.15	0.20	0.25	0.30	0.35	0.40	0.45
0.08	0.117	0.130	0.143	0.163	0.195	0.228	0.261	0.293	0.326	0.359
0.10	0.127	0.140	0.153	0.173	0.206	0.239	0.271	0.304	0.337	0.369
0.12	0.138	0.151	0.164	0.184	0.216	0.249	0.282	0.314	0.347	0.380
0.15	0.153	0.167	0.180	0.199	0.232	0.265	0.297	0.330	0.363	0.396
0.20	0.180	0.193	0.206	0.226	0.258	0.291	0.324	0.356	0.389	0.422
0.25	0.206	0.219	0.232	0.252	0.284	0.317	0.350	0.383	0.415	0.448
0.30	0.232	0.245	0.258	0.278	0.311	0.343	0.376	0.409	0.442	0.474
0.35	0.258	0.271	0.284	0.304	0.337	0.370	0.402	0.435	0.468	0.500
0.40	0.285	0.298	0.311	0.330	0.363	0.396	0.428	0.461	0.494	0.527
0.45	0.311	0.324	0.337	0.357	0.389	0.422	0.455	0.487	0.520	0.553

Bolt and Nut Fine-Screw Threads
JIS B 0207 thread standard (ISO 724)

Between Threads, μ_s	Coefficient of Friction K: Between Bearing Surfaces, μ_w									
	0.08	0.10	0.12	0.15	0.20	0.25	0.30	0.35	0.40	0.45
0.08	0.106	0.118	0.130	0.148	0.177	0.207	0.237	0.267	0.296	0.326
0.10	0.117	0.129	0.141	0.158	0.188	0.218	0.248	0.278	0.307	0.337
0.12	0.128	0.140	0.151	0.169	0.199	0.229	0.259	0.288	0.318	0.348
0.15	0.144	0.156	0.168	0.186	0.215	0.245	0.275	0.305	0.334	0.364
0.20	0.171	0.183	0.195	0.213	0.242	0.272	0.302	0.332	0.361	0.391
0.25	0.198	0.210	0.222	0.240	0.270	0.299	0.329	0.359	0.389	0.418
0.30	0.225	0.237	0.249	0.267	0.297	0.326	0.356	0.386	0.416	0.445
0.35	0.252	0.264	0.276	0.294	0.324	0.353	0.383	0.413	0.443	0.472
0.40	0.279	0.291	0.303	0.321	0.351	0.381	0.410	0.440	0.470	0.500
0.45	0.306	0.318	0.330	0.348	0.378	0.408	0.437	0.467	0.497	0.527

A **low** nut factor gives a **higher preload and clamping force** but puts the bolt **closer to yield** while a **high** nut factor gives a **lower preload and clamping force** but the capacity of the joint to resist external tensile loads has been reduced



When tightening a bolt, the same amount of torque applied to the assembly will result in more of the energy being used on overcoming friction rather than applying load to the bolt!
All things being equal, the same Torque applied to a DRY bolt will end up with LESS preload than the same amount of Torque being applied to a well lubricated bolt!
Of course, a well lubricated connection, will more easily loosen spontaneously! Below is a summarised chart of the ISO 898-1 mechanical properties for bolts which are most widely used in fastening. Throughout our calculations and testng we have adhered to the most common convention of bolt design
Proof load is defined as the maximum tensile force that can be applied to a bolt that will not result in plastic deformation. A material must remain in its elastic region when loaded up to its proof load typically between 85-95% of the yield strength.

Clamp L:oad (preload) - For a reasonable factor of safety, use 70% to 80% of the Bolt rating. Acceptable Pre-Load load is typically 75% of Proof load but we have used 70%.

Mechanical Property as per ISO 898-1		Property Class					
		4.6	6.8	8.8<=M16	8.8>M16	10.9	12.9
Tensile Strength, N/mm² Rm	nominal	400	600	900	900	1040	1200
	min	420	600	800	830	1000	1220
Yield Strength, N/mm² Rm	nominal	320	480	640	640	900	1080
	min		480	640	660	940	1100
Stress Under Proof Load Rp0.2, N/mm²	nominal	225	440	580	600	830	970
Vickers Hardness, HV	max	220	250	320	335	380	435
	min	120	190	2250	255	320	385
Brinell Hardness, HB	max	209	238	304	315	360	415
	min	114	181	238	240	305	365
Rockwell C Hardness, HRC	max				34	39	44
	min				22	32	39

Please turn over to read the Torque and Target preload tables for different lubrication and bolt class combinations

K-factor of 0.153 would be if something like **Graphite Paste** is used
K-factor of 0.173 if a **lubricating oil** is used
K-factor of 0.258 is if no lubrication is used and the bolted **connection is dry.**

Match Engineering

Anti-loosening Conical Wedge Lock Washer Pairs for Bolted Connections.

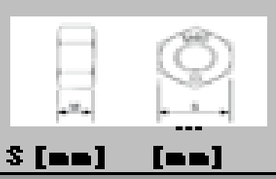
Scan for more online help

Or do you need to contact us?

Torque and target preload tables for different lubrication and bolt class combinations
Mechanical Properties as per ISO 898-1

K-factor of 0.153 would be if something like **Graphite Paste** is used
K-factor of 0.173 if a **lubricating oi**l is used
K-factor of 0.258 is if no lubrication is used and the bolted **connection is dry.**

HEXAGON FULL NUTS DIN 934 / ISO 4032 Target Preload and Required Torque by Bolt Size and Property Class for Coarse Pitch at defined G_r (70%) for different lubrication scenarios (k-factor). Graphite Grease, WD40 & Dry



Bolt Size	S [mm]	... [mm]	Pitch Coarse [mm]	G_r = 70.00% Area [mm²]	70.00% factor	6.8 Preload [kN]	6.8 Torque [Nm]	8.8 Preload [kN]	8.8 Torque [Nm]	10.9 Preload [kN]	10.9 Torque [Nm]	12.9 Preload [kN]	12.9 Torque [Nm]
M12	10	19	1.75	84	0.206	26	64	34	83	49	121	57	142
					0.258		80		106		152		177
M14	11	22	2	115	0.153	35	75	47	100	67	143	78	167
					0.206		101		135		193		225
					0.258		126		169		242		282
M16	13	24	2	157	0.153	48	118	64	156	91	223	107	261
					0.206		158		210		301		351
					0.258		198		263		377		440
M18	15	27	2.5	192	0.153	59	162	81	222	111	307	130	353
					0.206		219		299		413		484
					0.258		274		374		517		606
M20	16	30	2.5	245	0.153	76	233	103	315	142	435	166	509
					0.206		313		424		586		685
					0.258		392		531		733		858
M22	18	32	2.50	303	0.153	93	313	127	429	176	591	206	693
					0.206		421		577		796		933
					0.258		528		723		997		1168
M24	19	36	3	353	0.153	109	400	148	545	205	753	240	880
					0.206		539		733		1014		1185
					0.258		675		918		1270		1484
M27	22	41	3.00	459	0.153	141	582	193	796	267	1102	312	1288
					0.206		784		1071		1483		1734
					0.258		982		1342		1858		2171
M30	24	46	4	561	0.153	173	794	236	1082	326	1497	381	1748
					0.206		1069		1457		2016		2353
					0.258		1339		1825		2525		2947
M33	26	50	4	694	0.153	214	1080	292	1472	403	2036	471	2379
					0.206		1455		1982		2741		3203
					0.258		1822		2483		3433		4011
M36	29	55	4.5	817	0.153	252	1388	343	1889	475	2614	555	3056
					0.206		1869		2544		3520		4114
					0.258		2341		3186		4408		5153
M39	31	60	4.5	976	0.153	301	1796	410	2448	567	3383	663	3956
					0.206		2418		3296		4555		5326
					0.258		3029		4127		5705		6670
M42	34	65	5	1120	0.153	345	2211	470	3023	651	4181	761	4887
					0.206		2985		4070		5630		6580
					0.258		3738		5097		7051		8241
M45	36	70	5	1310	0.153	404	2782	550	3788	761	5240	890	6124
					0.206		3745		5100		7055		8246
					0.258		4690		6388		8836		10327
M48	38	75	5.5	1470	0.153	453	3327	617	4534	854	6273	998	7330
					0.206		4479		6105		8445		9869
					0.258		5610		7646		10577		12361
M52	42	80	5.5	1760	0.153	542	4312	739	5881	1023	8136	1195	9507
					0.206		5806		7918		10954		12801
					0.258		7271		9917		13719		16032
M56	45	85	6	2030	0.153	625	5355	853	7305	1179	10105	1378	11810
					0.206		7210		9836		13606		15901
					0.258		9030		12318		17040		19915
M60	48	90	6	2360	0.153	727	6674	991	9099	1371	12588	1602	14710
					0.206		8986		12251		16948		19806
					0.258		11254		15344		21226		24805
M64	51	95	6	2680	0.153	825	8078	1126	11022	1557	15247	1820	17819
					0.206		10877		14840		20529		23991
					0.258		13622		18586		25711		30047
M68	54	100	6	3060	0.153	943	9811	1285	13371	1778	18497	2078	21616
					0.206		13210		18003		24905		29104
					0.258		16544		22548		31192		36451
M72	58	95	6	3430	0.153	1056	11633	1441	15870	1993	21953	2329	25656
					0.206		15663		21367		29557		34544
					0.258		19616		26761		37018		43264
M76	61	95	6	3858	0.153	1188	13814	1620	18842	2242	26064	2620	30461
					0.206		18599		25369		35093		41013
					0.258		23294		31773		43951		51365
M80	64	100	6	4311	0.153	1328	16255	1811	22162	2505	30658	2927	35823
					0.206		21885		29839		41278		48240
					0.258		27410		37371		51697		60417

G_r = Ratio of yield point. When tightening according to guidelines and with no deviation, this is the pre-stress achieved expressed as % of yield point.

Checklist before tightening.

1. Have you decided on what lubrication you will use for your bolted connection?
2. Have you worked out what Torque you should apply to achieve your desired preload?
3. The maximum preload you apply should be around 80% of the bolt's proof load.
4. Are you using the Wedge Lock Washers as a Pair so ha hey can work together?