Prestressed bolt connection

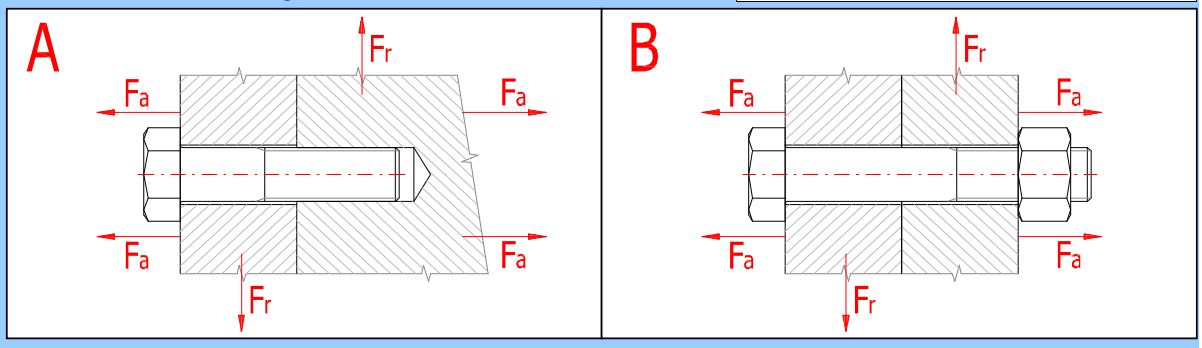
i **Calculation without errors.**

ii ☐ **Project information**

? **Input section**

1.0 ☑ Loading of the connection, basic parameters of the calculation.

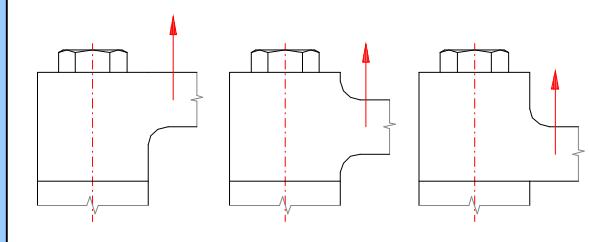
1.1	Calculation units	Imperial (lbf, in, HP....)	
1.2	**Loading conditions, connection type**		
1.3	Design of the bolt connection	B ... Bolt connection with a through bolt	
1.4	Loading of the bolt connection	Loading in the bolt axis	
1.5	The course of loading	Repeated loading	

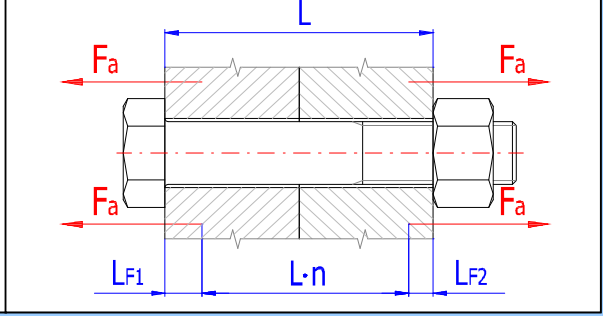


1.6	**Loading of the connection**				
1.7	Maximum axial force	F_{amax}	2000.00		[lb]
1.8	Minimum axial force	F_{amin}	0.00		[lb]
1.9	Maximum radial force	F_r	0.00		[lb]

2.0 ☑ Operational and mounting parameters of the connection.

2.1	Desired coefficient of tightness (prestressing) of the connection	q_a	0.500		
2.2	Desired safety against side shift	q_r	1.000		
2.3	Required residual prestressing of clamped parts of the connectio	F_{2min}	1000.00	☑	[lb]
2.4	Desired safety of the bolt at the yield point	n_s	1.500		
2.5	Friction coefficient in threads	μ_t	0.150		
2.6	Friction coefficient in seating face of the head (nut) of the bolt	μ_c	0.150		
2.7	Friction coefficient between he connected surfaces	μ_q	0.200		
2.8	Consider additonal bending stresses		No		
2.9	Deviation of perpendicularity of the bolt head seating surface	δ	0.100		[°]
2.10	Assembly temperature	T_0	68.0		[° F]
2.11	Consider effects of operational temperature to connection prestressing		No		
2.12	Operational temperature of the bolt	T_b	300.0		[° F]
2.13	Operational temperature of the clamped parts	T_m	300.0		[° F]
2.14	☐ The connection is loaded only at the operational temperature				
2.15	Consider reduction of mounting prestressing using deformation of the joint		Yes		
2.16	Plastic pernament deformation (settlement) of the connection	ΔL	0.00070		[in]
2.17	**Factor of implementation of operational force**				
2.18	◉ Coefficient of implementation of the operational force	n	0.500		
2.19	○ Distance of the point of action of the force from bolt head	L_{F1}	0.000		[in]
2.20	Distance of the point of action of the force from the nut	L_{F2}	0.000		[in]

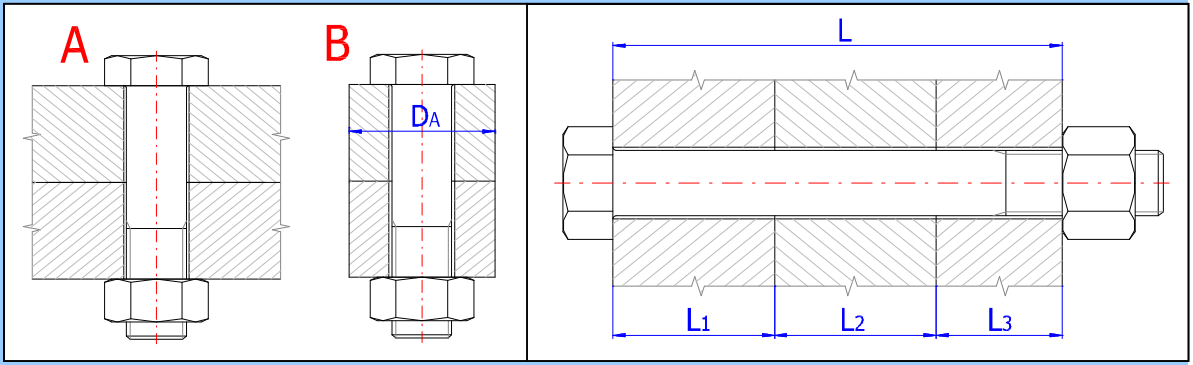




2.21	**Parameters of connecion exposed to dynamic (fatigue) loading**			
2.22	Special modification of the connection		Standard design of the connection	
2.23	Thread design		Cut thread	
2.24	Desired service life of the connection in cycles		1.0E+09	
2.25	Desired reliability of the connection		99.5	[%]
2.26	Desired dynamic (fatigue) safety	n_f	2.000	

3.0 ☑ `Design, dimensions and material of connected parts.

3.1	Design of connected parts		A ... Plate	
3.2	Number of clamped parts	i	3	
3.5	Total height of the clamped parts	L	4.500	[in]



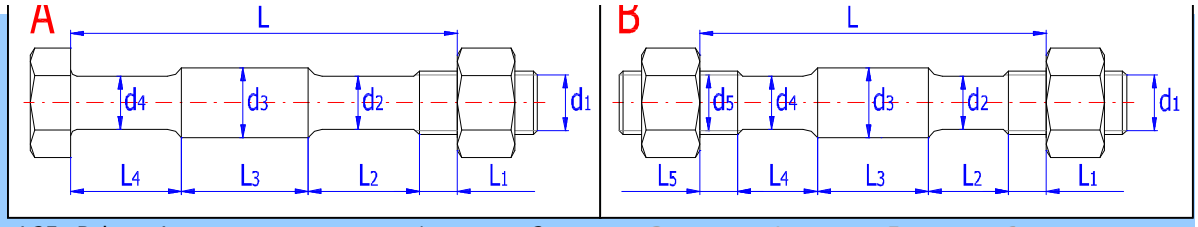
3.6	L_i	E	α	p_A	Material	AISI/SAE/ASTM
Part 1	0.500	29000	8.9	91	Stainless steel 304	
Part 2	3.000	16000	5.9	109	Gray cast iron A48-35	
Part 3	1.000	29000	6.9	77	High-strength structual steel A1011 HSLAS Grade 45 Class 2	

4.0 ☑ Design of connecting bolt.

4.1	Bolt type, material standard		Carbon and alloy steel bolts [SAE J429]	
4.2	**Preliminary design of minimum thread diameters**			1/1

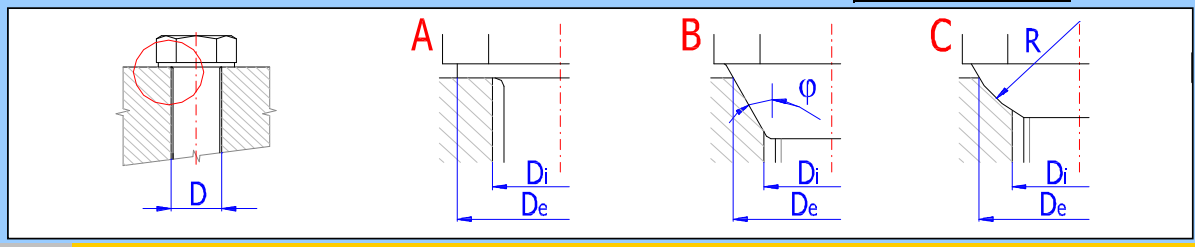
	SAE 1	SAE 2	SAE 4	SAE 5	SAE 5.1	SAE 7	SAE 8	SAE 8.1
MC	M14	M12	M8	M10	M10	M8	M8	M8
MF	M14	M12	M8	M8	M8	M8	M8	M8
UNC	9/16	7/16	3/8	3/8	3/8	5/16	5/16	5/16
UNF	1/2	7/16	5/16	3/8	3/8	5/16	5/16	5/16
UNEF	1/2	7/16	5/16	5/16	5/16	5/16	5/16	5/16

4.3	**Material of the bolt**			
4.4	Strength class (Material) of the bolt		SAE 5	
4.5	Modulus of elasticity in tension	E	30000	[ksi]
4.6	Ultimate tensile strength	S_u	120	[ksi]
4.7	Yield strength	S_y	92	[ksi]
4.8	Heat expansion coefficient	α	6.2	[10^{-6}/°F]
4.9	Density	ρ	490	[lb/ft^3]
4.11	**Thread parameters**			
4.12	Thread type		Unified inch thread - Coarse series	
4.13	Automatic bolt design			
4.14	Thread size		1/2	
4.15	Basic major diameter	d	0.5000	[in]
4.16	Thread pitch	p	0.0769	[in]
4.17	Minor diameter	d_r	0.4001	[in]
4.18	Pitch diameter	d_m	0.4500	[in]
4.19	**Design and geometry of the bolt**			
4.20	Bolt type		A ... Through-bolt with head and nut	
4.21	Design of the bolt		Solid bolt	
4.22	Design of the bolt head		Hexagonal head	
4.23	Number of bolt sections with different cross-section areas	i	2	
4.24	Total height of the clamped parts	L	4.5	[in]



4.25	Bolt section		1	2	3	4	5	6	
4.26	Length	L_i	1.500	3.000	0.000	0.000	0.000	0.000	[in]
4.27	Diameter	d_i	0.400	0.500	0.000	0.000	0.000	0.000	[in]

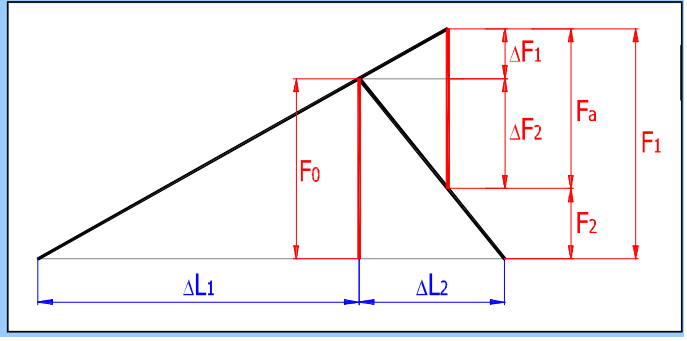
4.28	Inner diameter of the hollow bolt	d_h	0.000	[in]
4.29	**Geometry of the connection**			
4.30	Design of seating faces below heads (nuts) of bolts		A ... Annulus seating face ☑	
4.31	Hole diameter	D	0.516	[in]
4.32	Outer diameter of the seating face	D_e	0.750	[in]
4.33	Inner diameter of the seating face	D_i	0.516	[in]



Results section

5.0 ☑ Prestressing, force conditions and operational diagram of the connection.

5.1	**Stiffness constants of the connection**			
5.2	Stiffness of the connecting bolt	c_b	1047846.09	[lb/in]
5.3	Stiffness of the clamped parts	c_m	8057436.85	[lb/in]
5.4	Resulting stiffness od the group of surcharged parts of the joint	c_1	983871.3	[lb/in]
5.5	Resulting stiffness of the group of relieved parts of the joint	c_2	16114873.7	[lb/in]
5.6	**Assembly preload of the bolt connection**			
5.7	Maximum axis component of the operational force	F_a	2000	[lb]
5.8	Maximum radial component of the operational force	F_r	0	[lb]
5.9	Minimum needed clamping force for transfer of the radial force	F_{cmin}	0	[lb]
5.10	Part of the operational force additionally loading the bolt	ΔF_1	115.08	[lb]
5.11	Part of the operational force relieving the clamped parts	ΔF_2	1884.92	[lb]
5.12	Minimum needed assembly preload of the joint	F_{0min}	3535	[lb]
5.13	Assembly preload of the joint	F_0	3535.0 ☑	[lb]
5.14	Tightening torque	M	27.65	[lb ft]
5.15	**Force conditions of the loaded connection**			
5.16	Change of prestresssing due to heating of the connection	ΔF_{0T}	0.00	[lb]
5.17	Loss of prestressing due to deformation of the connection	ΔF_{0L}	-649.08	[lb]
5.18	Operating prestressing of the joint	F_0'	2885.92	[lb]
5.19	Residual prestressing of clamped parts of the connection	F_2	1001.00	[lb]
5.20	Resulting internal axis force in the bolt	F_1	3001.00	[lb]
5.21	Coefficient of tightness (prestressing) of the connection	q_a	0.500	
5.22	Safety against side shift	q_r	0.000	



6.0	☑ **Strength checks of statically loaded bolt connections.**				
6.1	**Strength check of connections in the working state**				
6.2	Internal axis force in the bolt	F_1	3001.00		[lb]
6.3	Tensile stress in bolt core from the axis force	σ	21.15		[ksi]
6.4	Torsional stress in bolt core from tightening moment	τ	10.87		[ksi]
6.5	Additional bending stress	σ_b	0.00		[ksi]
6.6	Resulting reduced stress in the bolt core	σ_{red}	23.15		[ksi]
6.7	Yield point of the bolt material	S_y	92		[ksi]
6.8	Safety at yield point	n	3.97		
6.9	**Strength check of connections in the assembly state**				
6.10	Assembly preload of the joint	F_0	3535.00		[lb]
6.11	Tensile stress in bolt core from the assembly preload	σ	24.91		[ksi]
6.12	Resulting reduced stress in the bolt core	σ_{red}	31.23		[ksi]
6.13	Allowable stress (90% Sy)	σ_A	83		[ksi]
6.14	**Check of pressure in seating face of the bolt head**				
6.15	Pressure in the bolt head (nut) seating face	p	12.90		[ksi]
6.16	Permitted pressure in the marginal clamped part	p_A	77		[ksi]
6.17	**Strength check of connections for maximum prestressing**				
6.18	Maximum operating prestressing of the joint	$F_0'_{max}$	3535.00		[lb]
6.19	Maximum internal axis force in the bolt	F_{1max}	3650.08		[lb]
6.20	Tensile stress in bolt core from the maximum axis force	σ_{max}	25.72		[ksi]
6.21	Resulting reduced stress in the bolt core	σ_{red}	27.39		[ksi]
6.22	Maximum pressure in the bolt head (nut) seating face	p_{max}	15.69		[ksi]
7.0	☑ **Strength checks of dynamically loaded bolt connections.**				
7.1	**Strength check in the thread core**				
7.2	Medium axis force of the cycle	F_m	2943.46		[lb]
7.3	Amplitude of the axis force of the cycle	F_a	57.54		[lb]
7.4	Medium cycle stress in the thread core	σ_m	20.74		[ksi]
7.5	Cycle stress amplitude in the thread core	σ_a	0.41		[ksi]
7.6	Basic fatigue limit / for N cycles	σ_e' / N	54 | 1.0E+06		[ksi]
7.7	Fatigue limit in tension with a required service life	σ_f'	54		[ksi]
7.8	Corrected fatigue limit in tension of the given bolt	σ_f	9.1	☑	[ksi]
7.9	Max. fatigue strength of the bolt for the given course of loading	σ_A	7.02		[ksi]
7.10	Dynamic safety in tension	n_σ	17.32		
7.11	**Strength check in the reduced shank**				
7.12	Medium cycle stress in the reduced shank	σ_m	14.99		[ksi]
7.13	Cycle stress amplitude in the reduced shank	σ_a	0.29		[ksi]
7.14	Corrected fatigue limit in tension of the given bolt	σ_f	54	☑	[ksi]
7.15	Max. fatigue strength of the bolt for the given course of loading	σ_A	32.68		[ksi]
7.16	Dynamic safety in tension	n_σ	---		
	Supplements section				
8.0	☑ **Assembly parameters of the connection.**				
8.1	**Assembly preload of the joint**				
8.2	Minimum assembly preload	F_{0min}	3535.0		[lb] ☑
8.3	Tightening factor	α_A	1.70		
8.4	Maximum assembly preload	F_{0max}	6009.5		[lb]
8.5	**Tightening torque**				
8.6	Friction coefficient in threads (min/max)		0.120 | 0.180		
8.7	Friction coefficient in seating face of the head (nut) of the bolt (min/max)		0.100 | 0.200		
8.8	Minimum possible tightening torque	M_{min}	20.96		[lb ft]
8.9	Maximum possible tightening torque	M_{max}	58.38		[lb ft]
8.10	**Strength check of connections in the assembly state**				
8.11	Tensile stress in bolt core from the assembly preload	σ_{max}	42.35		[ksi]
8.12	Torsional stress in bolt core from tightening moment	τ_{max}	21.23		[ksi]
8.13	Resulting reduced stress in the bolt core	σ_{red}	56.09		[ksi]
8.14	Allowable stress (90% Sy)	σ_A	83		[ksi]

8.15	**Strength check of connections in the working state**			
8.16	Operating prestressing of the joint	$F_{0'max}$	5360.4	[lb]
8.17	Internal axis force in the bolt	F_{1max}	5475.5	[lb]
8.18	Tensile stress in bolt core from the axis force	σ_{max}	38.59	[ksi]
8.19	Resulting reduced stress in the bolt core	σ_{red}	42.74	[ksi]
8.20	Yield point of the bolt material	S_y	92	[ksi]
8.21	Safety at yield point	n	2.15	
8.22	**Check of pressure in seating face of the bolt head**			
8.23	Pressure in the bolt head (nut) seating face	p_{max}	23.53	[ksi]
8.24	Permitted pressure in the marginal clamped part	p_A	77	[ksi]
8.25	**Fatigue check of the connection**			
8.26	Medium cycle stress in the thread core	σ_m	38.18	[ksi]
8.27	Cycle stress amplitude in the thread core	σ_a	0.41	[ksi]
8.28	Max. fatigue strength of the bolt for the given course of loading	σ_A	5.80	[ksi]
8.29	Dynamic safety in tension	n_σ	14.29	

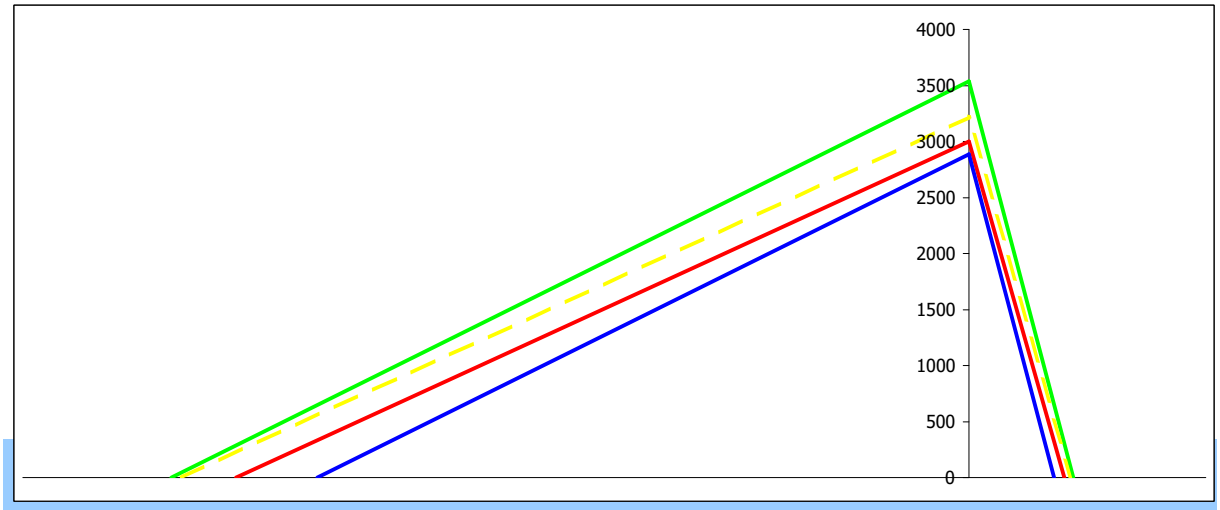
9.0 ☑ **Parameters of the coupling at specific working temperature.**

9.1	**Temperature of the connection**		Different temperatures at the connection ☐	
9.2	Assembly temperature	T_0	68.0	[° F]
9.3	Operational temperature of the bolt	T_b	500.0	[° F]
9.4	Operational temperature of the clamped parts	T_m	500.0	[° F]

9.5	**Material of the bolt**						☑
9.6	Modulus of elasticity in tension	E_{20}	30000	E_T	27700	[ksi]	
9.7	Heat expansion coefficient	$\alpha_{20\text{-}100}$	6.2	$\alpha_{T0\text{-}T}$	7.1	[10^{-6}/°F]	
9.8	Yield strength	S_{y20}	92	S_{yT}	72	[ksi]	

9.9	**Material of connected parts.**	E_{20}	E_T	$\alpha_{20\text{-}100}$	$\alpha_{T0\text{-}T}$	☑
9.10	Stainless steel 304	29000	26600	8.9	9.3	
9.11	Gray cast iron A48-35	16000	15000	5.9	6.8	
9.12	High-strength structual steel A1011 HSLAS Grade 45 Class 2	29000	26900	6.9	7.8	

9.15	**Parameters of the connection**				
9.16	Assembly preload of the joint	F_0	3535.0	[lb]	☑
9.17	Operating prestressing of the joint at the temperature T0	F_0'	2885.9	[lb]	
9.18	Change of prestresssing due to heating of the connection				
9.19	- due to thermal expansion	ΔF_{0Ta}	333.1	[lb]	
9.20	- due to change in stiffness	ΔF_{0Tc}	-219.4	[lb]	
9.21	Prestressing of the joint at the operating temperature	F_{0T}'	2999.6	[lb]	
9.22	Residual prestressing of clamped parts of the connection	F_{2T}	1114.1	[lb]	
9.23	Coefficient of tightness (prestressing) of the connection	q_{aT}	0.557		
9.24	Safety against side shift	q_{rT}	0.000		
9.25	Resulting internal axis force in the bolt	F_{1T}	3114.1	[lb]	
9.26	Tensile stress in bolt core from the axis force	σ_T	21.9	[ksi]	
9.27	Resulting reduced stress in the bolt core	σ_{redT}	23.9	[ksi]	
9.28	Safety at yield point	n_T	3.02		



10.0 ☑ Graphical output, CAD systems

10.1	2D drawing output to:	DXF File			
10.2	Design of the bolt head	Hexagonal head			
10.3	Design of the nut	Hexagonal nut			
10.4	Number of washers below the bolt head	0			
10.5	Number of washers below the nut	1			
10.6	Calculation clamping height	L	4.5		[in]
10.7	Actual height of clamped parts	L_C	4.500	☑	[in]