Design A Lead Screw For Lathe Machine

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- CHOOSE AND JUSTIFY THE OPTIMAL SOLUTION
- DEVELOPE A PROTOTYPE
- TEST & EVALUATE

FORMULAS & IMPORTANT DIAGRAMS (SHIGLEY'S BOOK)

$$T_R = \frac{F d_m}{2}\left(\frac{l + \pi f d_m}{\pi d_m - f l}\right) \tag{8–1}$$

$$T_L = \frac{F d_m}{2}\left(\frac{\pi f d_m - l}{\pi d_m + f l}\right) \tag{8–2}$$

$$T_R = \frac{F d_m}{2}\left(\frac{l + \pi f d_m \sec\alpha}{\pi d_m - f l \sec\alpha}\right) \tag{8–5}$$

$$e = \frac{T_0}{T_R} = \frac{F l}{2\pi T_R} \tag{8–4}$$

$$\tau = \frac{16T}{\pi d_r^3} \tag{8–7}$$

$$\sigma_B = -\frac{F}{\pi d_m n_t p/2} = -\frac{2F}{\pi d_m n_t p} \tag{8–10}$$

$$\sigma_x = \frac{6F}{\pi d_r n_t p} \tag{8-11}$$

$$\sigma_y = -\frac{4F}{\pi d_r^2} \tag{8-8}$$

Figure 8–3

(*a*) Square thread;
(*b*) Acme thread.

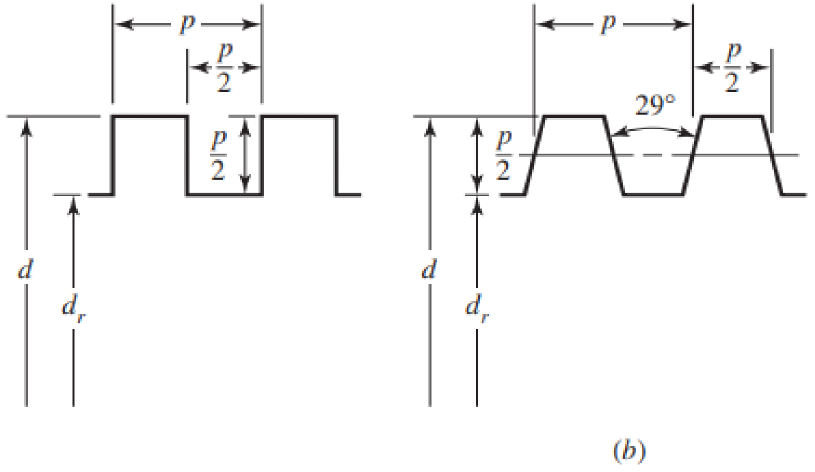
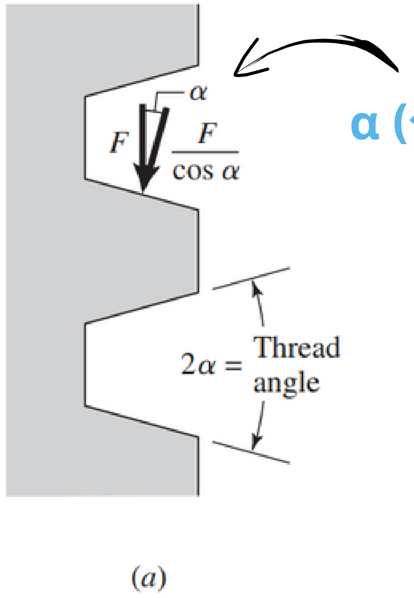


Figure 8–7

(*a*) Normal thread force is increased because of angle α; (*b*) thrust collar has frictional diameter d_c.



α (↑) <- Friction Induced (↑)

Why square thread should be preferred?

- High Efficiency
- Low Stress developed
- Exert minimum Pressure on nut

Theoretically BEST

Then why industry uses ACME/Trapezoidal threaded screws?

- Easy to Machine
- Cheaper to make
- Wider Area → Stronger → carry more LOADS
- Transmit more TORQUE → resistant to wear

Practically BEST

Why ACME over Trapezoidal ?

Priority $\longrightarrow$ Lathe machine $\longrightarrow$ Threading

For Threading:

- Precise movement
- Finer pitch
- Quick Engagement & Disengagement

Torque

T(raise) N.m	T(lower) N.m
3.35	-0.75
3.86	-0.24
4.11	0.01
4.37	0.27
5.13	1.03
5.64	1.54
6.92	2.82

Square

T(raise) N.m	T(lower) N.m
3.40	-0.71
3.92	-0.18
4.18	0.08
4.44	0.34
5.23	1.13
5.76	1.66
7.08	2.98

ACME

Example: ((3.35 - 3.4)/3.35) % = 1.5% increase

Properties of Stainless Steel

SS Grade 304

- Sut = 579 MPa
- Sy = 205 MPa
- Low cost

SS Grade 316

- Sut = 621 MPa
- Sy = 291 MPa
- Better corrosion resistance

Fig: Atlas steels reference manual
(Section 9: Appendices, page 2)

COLOUR CODE

→ Okay for SS Grade *304* & *316*

→ Okay for SS Grade *316*

→ Allowable Stress for SS Grade *304* & *316*

→ Allowable Stress for SS Grade *316*

→ Okay for SS Grade *316* if Force change

Stress Analysis for varying Diameter

Major Diameter,d	Efficiency	Torsional Shear Stress (MPa)	Axial Stress (MPa)	Bearing Stress (MPa)	Bending Stress (MPa)	Force, F
6	60.79%	266.69	509.30	154.83	580.60	
8	52.81%	90.95	226.35	110.59	387.06	
9	49.55%	61.05	166.30	96.77	331.77	**5.5 KN** (max, 316)
10	46.66%	43.43	127.32	86.01	290.30	
13	39.70%	19.63	67.34	64.51	211.13	
15	36.11%	13.08	48.22	55.29	178.65	
20	29.44%	6.04	25.15	40.74	129.02	

→ **Square**

Major Diameter,d	Efficiency	Torsional Shear Stress (MPa)	Axial Stress (MPa)	Bearing Stress (MPa)	Bending Stress (MPa)	Force, F
6	58.09%	270.17	493.07	149.89	562.10	
8	50.34%	92.37	219.14	107.07	374.74	
9	47.18%	62.07	161.00	93.68	321.20	**5.7 KN** (max, 316)
10	44.39%	44.19	123.27	83.27	281.05	
13	37.69%	20.02	65.20	62.46	204.40	
15	34.24%	13.35	46.68	53.53	172.96	
20	27.85%	6.18	24.35	39.45	124.91	

→ **ACME**

- **Force Increased**
- **Stress Decreased**

Stress Analysis for varying Pitch

PItch, p	Efficiency	Torsional Shear Stress (MPa)	Axial Stress (MPa)	Bearing Stress (MPa)	Bending Stress (MPa)	Force, F
1	34.54%	43.78	166.30	206.43	663.54	
2	52.81%	90.95	226.35	110.59	387.06	
3	63.98%	194.59	325.95	79.40	309.65	**5.6 KN** (max, 316)
4	71.39%	454.17	509.30	64.51	290.30	
5	76.53%	1255.32	905.41	56.30	309.65	
6	80.16%	4853.93	2037.18	51.61	387.06	
7	82.68%	43920.37	8148.73	49.15	663.54	

→ **Square**

- **Force Increased**
- **Stress Decreased**

PItch, p	Efficiency	Torsional Shear Stress (MPa)	Axial Stress (MPa)	Bearing Stress (MPa)	Bending Stress (MPa)	Force, F
1	32.74%	44.73	161.00	199.86	642.40	
2	50.34%	92.37	219.14	107.07	374.74	
3	61.21%	196.92	315.57	76.87	299.79	**5.8 KN** (max, 316)
4	68.46%	458.52	493.07	62.46	281.05	
5	73.51%	1265.26	876.58	54.51	299.79	
6	77.08%	4886.65	1972.29	49.96	374.74	
7	79.57%	44181.31	7889.18	47.59	642.40	

→ **ACME**

Stress Analysis for varying Diameter

Major Diameter,d	Efficiency	Torsional Shear Stress (MPa)	Axial Stress (MPa)	Bearing Stress (MPa)	Bending Stress (MPa)	Force, F
6	57.91%	270.42	491.94	149.55	560.81	
8	50.17%	92.47	218.64	106.82	373.88	
9	47.02%	62.14	160.63	93.47	320.47	**5.7 KN** (max, 316)
10	44.23%	44.25	122.99	83.08	280.41	
13	37.55%	20.05	65.05	62.31	203.93	
15	34.11%	13.37	46.57	53.41	172.56	
20	27.74%	6.19	24.29	39.36	124.63	

→ ACME

- Stress INCREASED

Major Diameter,d	Efficiency	Torsional Shear Stress (MPa)	Axial Stress (MPa)	Bearing Stress (MPa)	Bending Stress (MPa)	Force, F
6	58.09%	270.17	493.07	149.89	562.10	
8	50.34%	92.37	219.14	107.07	374.74	
9	47.18%	62.07	161.00	93.68	321.20	**5.7 KN** (max, 316)
10	44.39%	44.19	123.27	83.27	281.05	
13	37.69%	20.02	65.20	62.46	204.40	
15	34.24%	13.35	46.68	53.53	172.96	
20	27.85%	6.18	24.35	39.45	124.91	

→ Trapezoidal

Stress Analysis for varying Pitch

PItch, p	Efficiency	Torsional Shear Stress (MPa)	Axial Stress (MPa)	Bearing Stress (MPa)	Bending Stress (MPa)	Force, F
1	32.74%	44.73	161.00	199.86	642.40	
2	50.34%	92.37	219.14	107.07	374.74	
3	61.21%	196.92	315.57	76.87	299.79	**5.8 KN** (max, 316)
4	68.46%	458.52	493.07	62.46	281.05	
5	73.51%	1265.26	876.58	54.51	299.79	
6	77.08%	4886.65	1972.29	49.96	374.74	
7	79.57%	44181.31	7889.18	47.59	642.40	

→ **ACME**

Stress DECREASED (not torsional)

PItch, p	Efficiency	Torsional Shear Stress (MPa)	Axial Stress (MPa)	Bearing Stress (MPa)	Bending Stress (MPa)	Force, F
1	32.69%	44.80	160.63	199.40	640.93	
2	50.29%	92.47	218.64	106.82	373.88	
3	61.16%	197.09	314.84	76.69	299.10	**5.8 KN** (max, 316)
4	68.41%	458.83	491.94	62.31	280.41	
5	73.47%	1265.97	874.56	54.38	299.10	
6	77.05%	4889.02	1967.77	49.85	373.88	
7	79.54%	44200.19	7871.07	47.48	640.93	

→ **Trapezoidal**

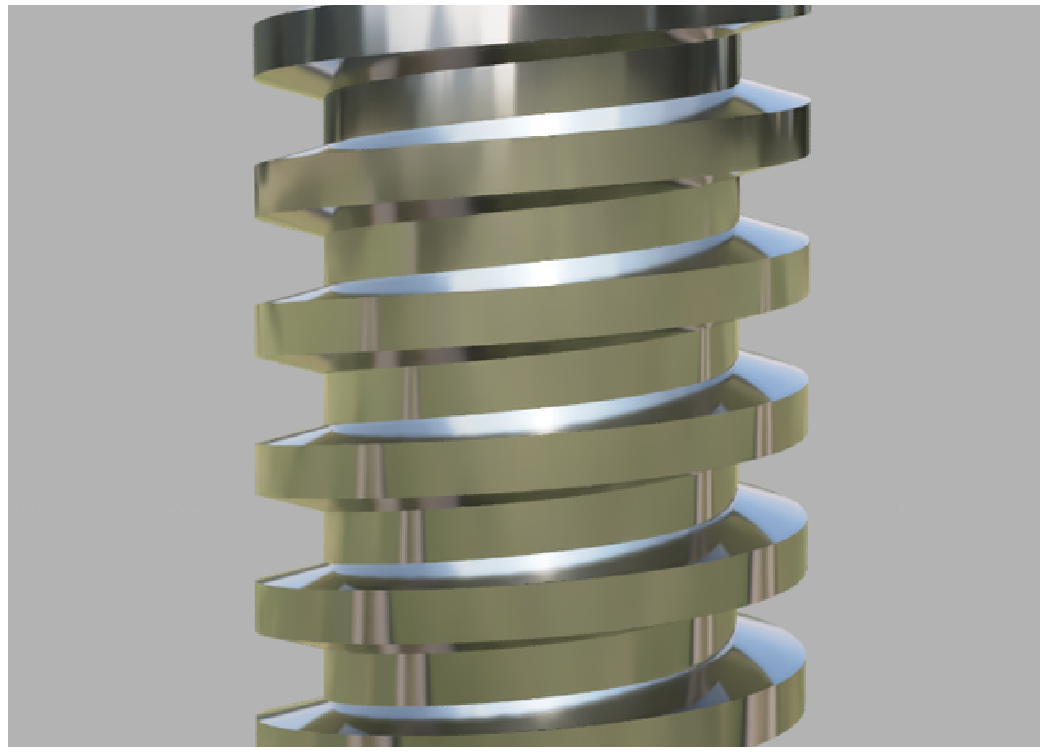
This is interesting !

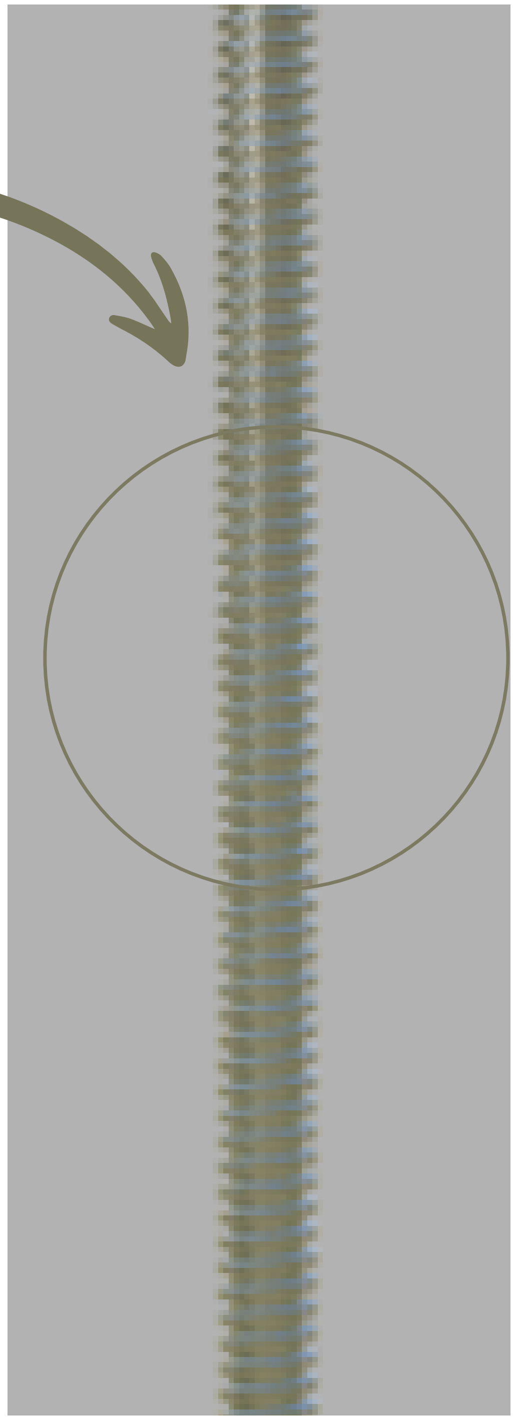
Diameter (same)	PItch (change)	Bending Stress (%, decrease)	Diameter (change)	PItch (same)	Bending Stress (%, decrease)
8	2 to 3	20%	8 to 9	2	14%
8	3 to 4	6%	9 to 10	2	12%
9	2 to 3	22%	8 to 9	3	16%
9	3 to 4	10%	9 to 10	3	14%

Changing PITCH creates more impact on STRESS

ALTERNATIVE DESIGNS (SS GRADE 316)

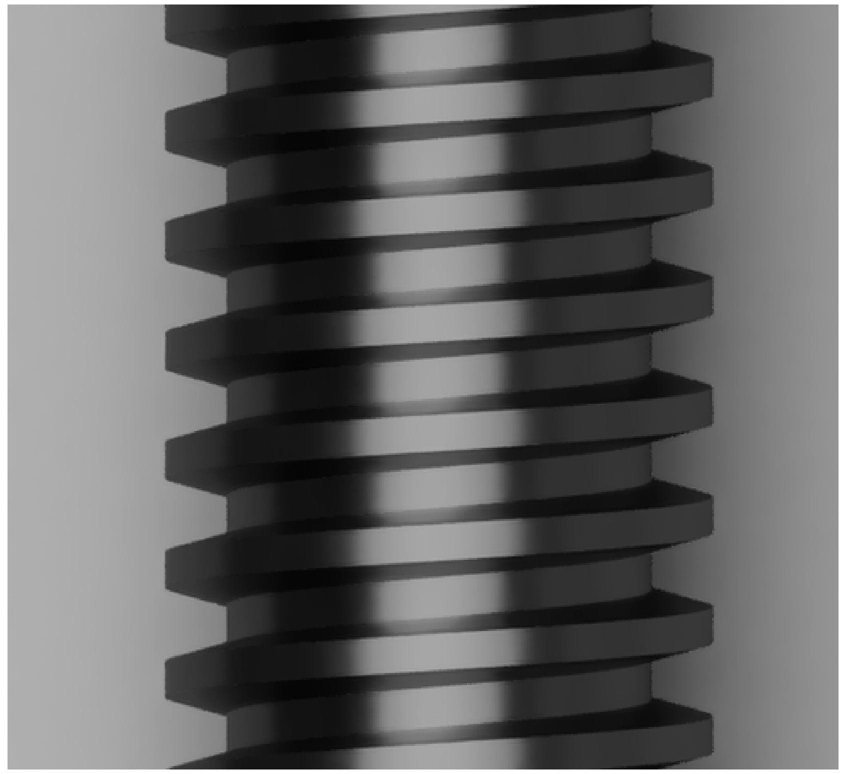
- d = 9 mm
- p = 2 mm

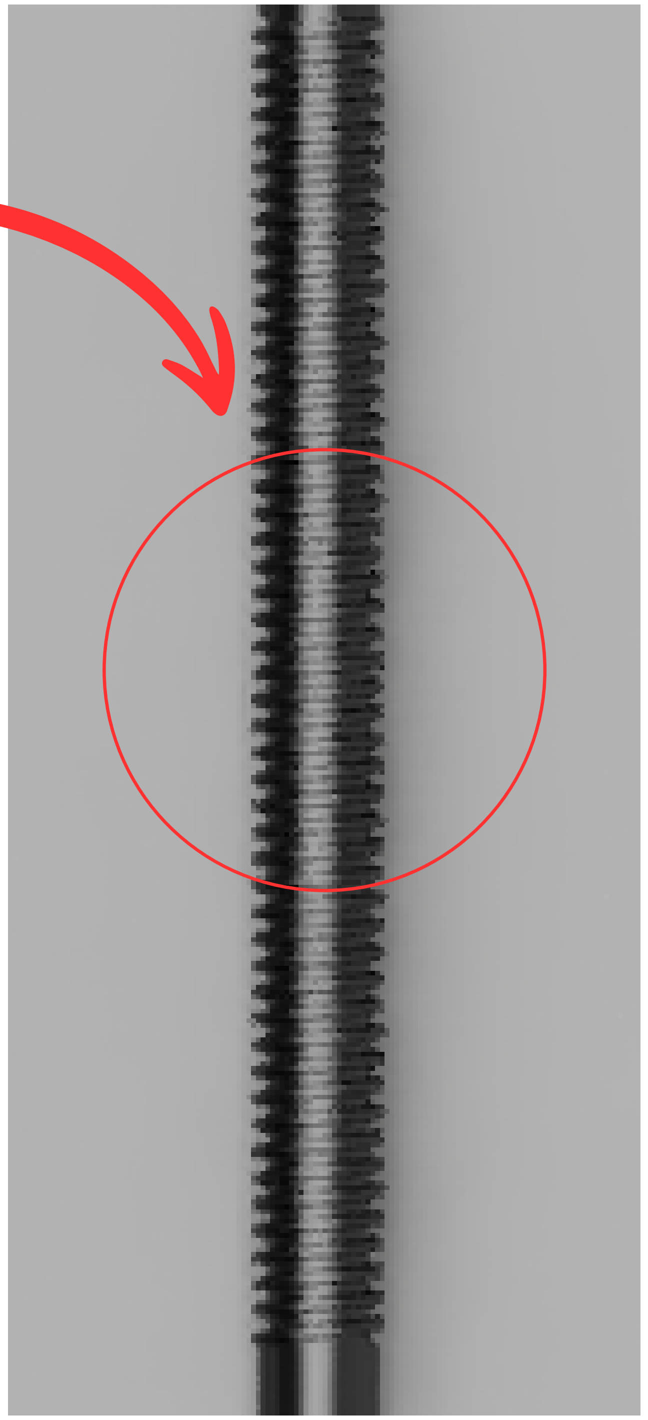




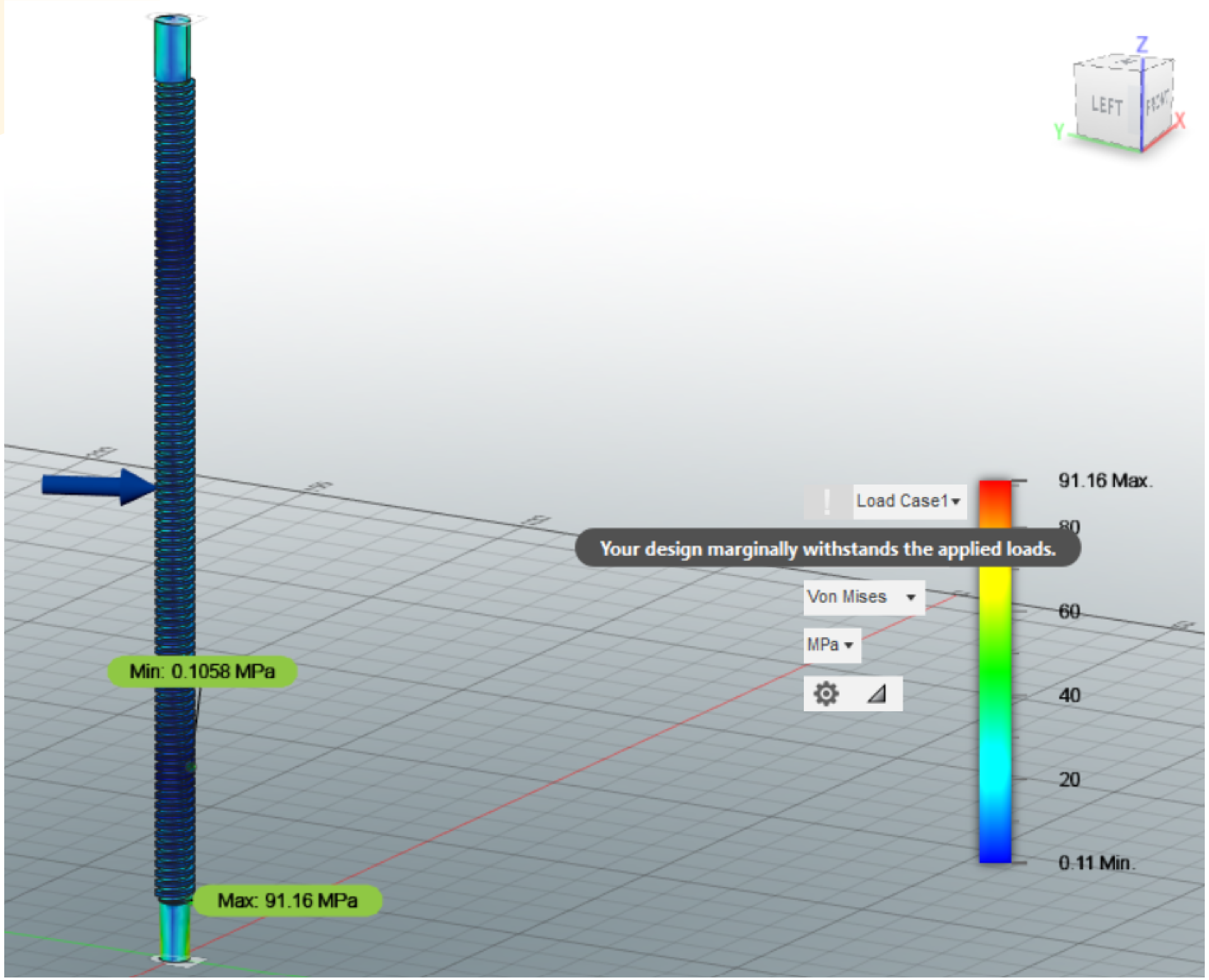
ACME
Thread Rendered (NEW)
<u>OPTIMAL SOLUTION</u>

- d = 10 mm
- p = 2 mm





Trapezoidal
Thread Rendered

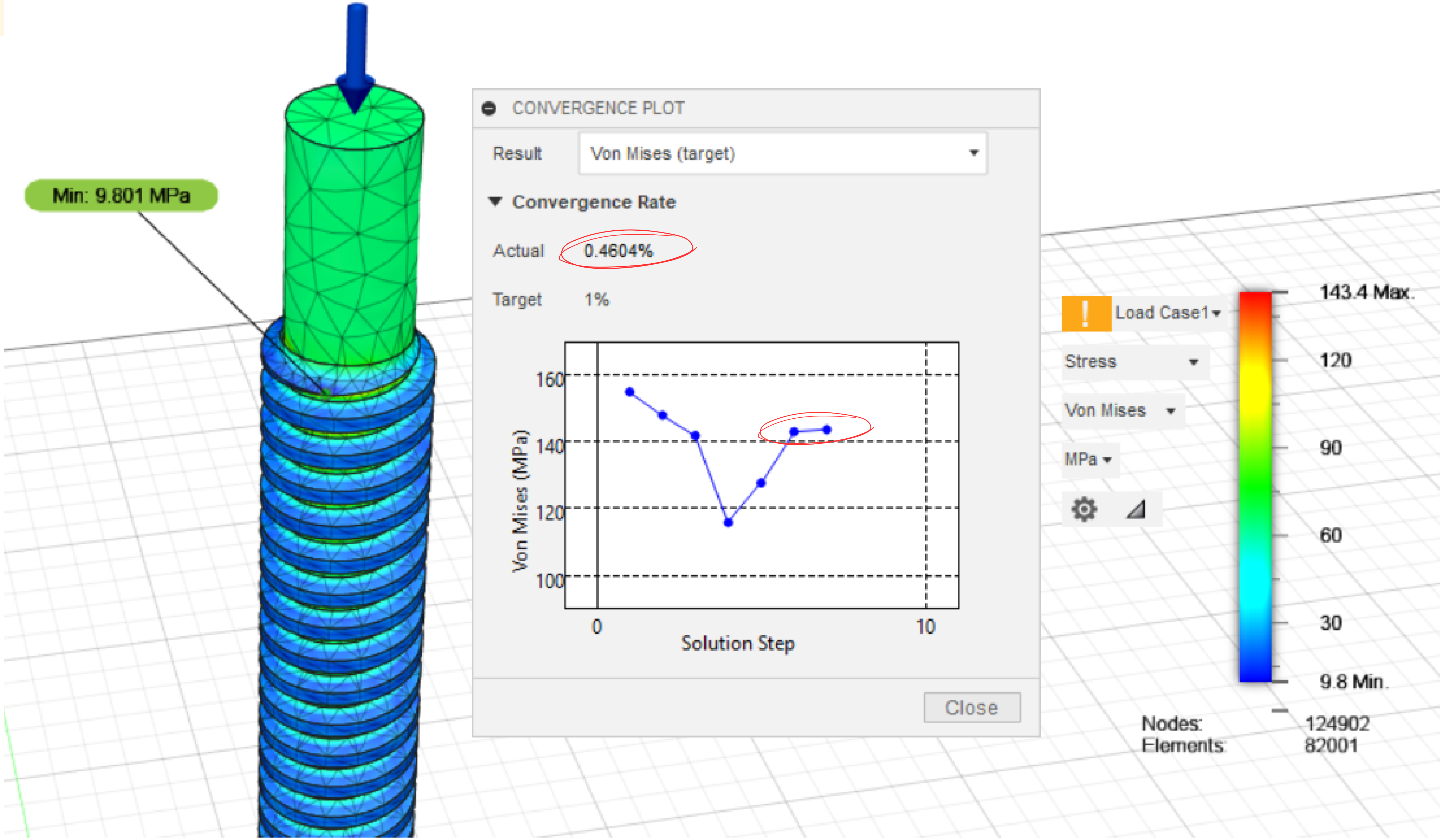


Force: 2000N
Material: SS 316L

Bending Stress analysis on ACME threaded lead screw using Fusion 360

(accuracy of solution)

Mesh Refinement



Force: <u>2000N</u>
Material: <u>SS 316L</u>
Solution Step: <u>10</u>

As the MESH is close enough, safe to assume OKAY.

Simulated on Fusion 360

THANK YOU