A10 Lead Screw Design

04 14 2026

Tensile Tester : 2kN axial tensile load

crosshead speed : 1-50 mm/min

lead screw min : 18 in → 24" → 2' reasonable

SAFETY FACTOR : 4

Leadscrew Diameter

Determining min diameter through axial stress.

★ 2 lead screws, SF=4

known	unknown
2kN maxload	σ_{max}
SF=4	A → diam
L=24"	$F_{leadscrew}$

www.roton.com/products/acme-lead-screws-nuts/general-information

↳ "All Acme lead screws 1 3/4" in diam and larger, are made of special quality medium carbon steel. Acme lead screws smaller than 1 3/4" are made from special quality low carbon steel. Sizes with material listed as "Stainless Steel" are made from 304 type stainless steel."

tensile yield σ_{small} = 20300 - 347000 psi or 140-2400 MPa (matweb - low carbon steel)

E_{small} = 26500 - 30900 ksi or 183-213 GPa

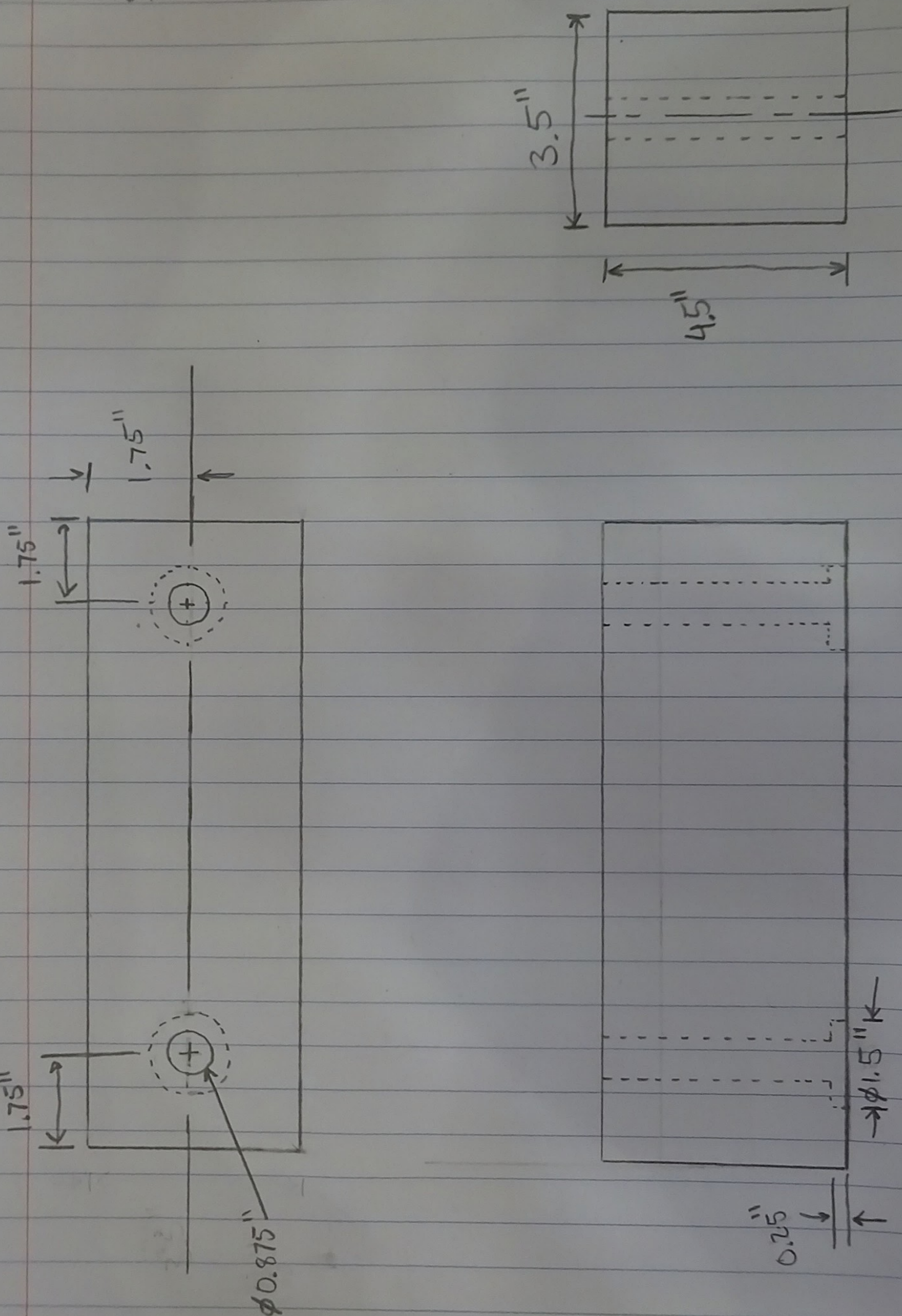
tensile yield σ_{large} = 33400 - 252000 psi (matweb - medium carbon steel)

E_{large} = 27100 - 30900 ksi

★ ductile materials → compressive strength ≈ tensile strength

- mechanicalc.com/reference/column buckling

Multi View Sketch



Scale: 1:3

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Final Material Selection

criteria: Tensile yield strength ≥ 42.8 psi
Elastic Modulus ≥ 362.745 ksi

Aluminum 1050-O (MatWeb

$\sigma_y = 4060$ psi ✓

$E = 10{,}000$ ksi ✓

more than suitable for our specifications

crosshead dims

4.5" x 12" x 3.5"

Simple Beam Deflection Analysis

Assumption

Simply supported, load at center

known

max load = 2kN

SF = 4

crosshead length = 12''

crosshead width = 3.5''

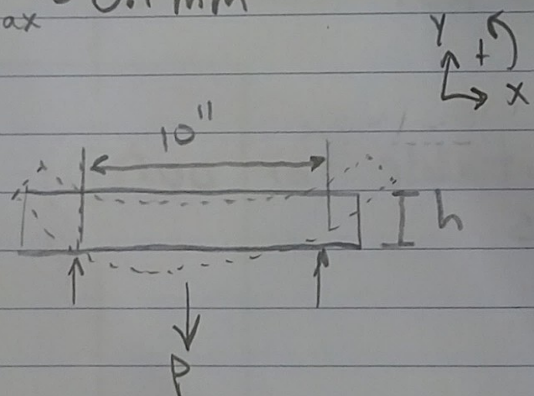
span ≈ 10''

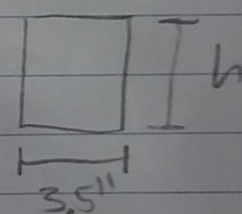
★ $\delta_{max} = 0.1$ mm

unknown

height

E (material properties)





$$\frac{\delta_{max}}{SF} = \frac{W l^3}{48 E I} \rightarrow E = \frac{W l^3 (SF)}{48\, \delta_{max}\, I} = \frac{W l^3 (SF)}{4\, \delta_{max}\, b h^3}$$

$$I = \frac{bh^3}{12}$$

Assumption

Use min height from stress analysis

$$E = \frac{(2{,}000\,N)\left(\frac{1\,lb}{4.45\,N}\right)(10'')^3(4)}{4\,(0.1\,mm)\left(\frac{1\,in}{25.4\,mm}\right)(3.5'')(4.48'')^3}$$

$\boxed{E = 362{,}745 \text{ psi minimum or } 362.745 \text{ ksi}}$

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$$\frac{\sigma_{axial}}{SF} = \frac{F}{A} = \frac{(4)\,2{,}000N\left(\frac{1\,lb}{4.45N}\right)}{(12'')(3.5'')} = 42.8\ psi$$

Assumption

Simply Supported, Load at center

$$\frac{\sigma_{bending}}{SF} = -\frac{W\,l}{4Z} = -\frac{3W\,l\,(SF)}{bd^3}$$

$$Z = \frac{bd^3}{12} \qquad d = \sqrt[3]{\frac{3W\,l\,(SF)}{b\,\sigma_{bending}}}$$

Assumption

$\sigma_{axial} = \sigma_{bending}$ (SF already accounted for)

$$h = d = \sqrt[3]{\frac{3(2{,}000N)\left(\frac{1\,lb}{4.45N}\right)(10'')\cancel{(4)}}{(3.5'')(42.8\,psi)}}$$

$$\boxed{h = 4.48\ \text{inches}\ \underline{\text{minimum}}}$$

material, minimum tensile yield 42.8 psi

many options here's a few: (MatWeb.com)

Aluminum Alloy $T_y = 180 - 106000\,psi$ $E = 6.96 - 49600\,ksi$

Medium Alloy Steel $T_y = 29500 - 290000\,psi$ $E = 2900 - 30000\,ksi$

Low Alloy Steel $T_y = 16000 - 347000\,psi$ $E = 26500 - 30900\,ksi$

Design the Crosshead

Research appropriate length of crosshead

crosshead length ~ $\frac{1}{2}$ lead screw length → 12"

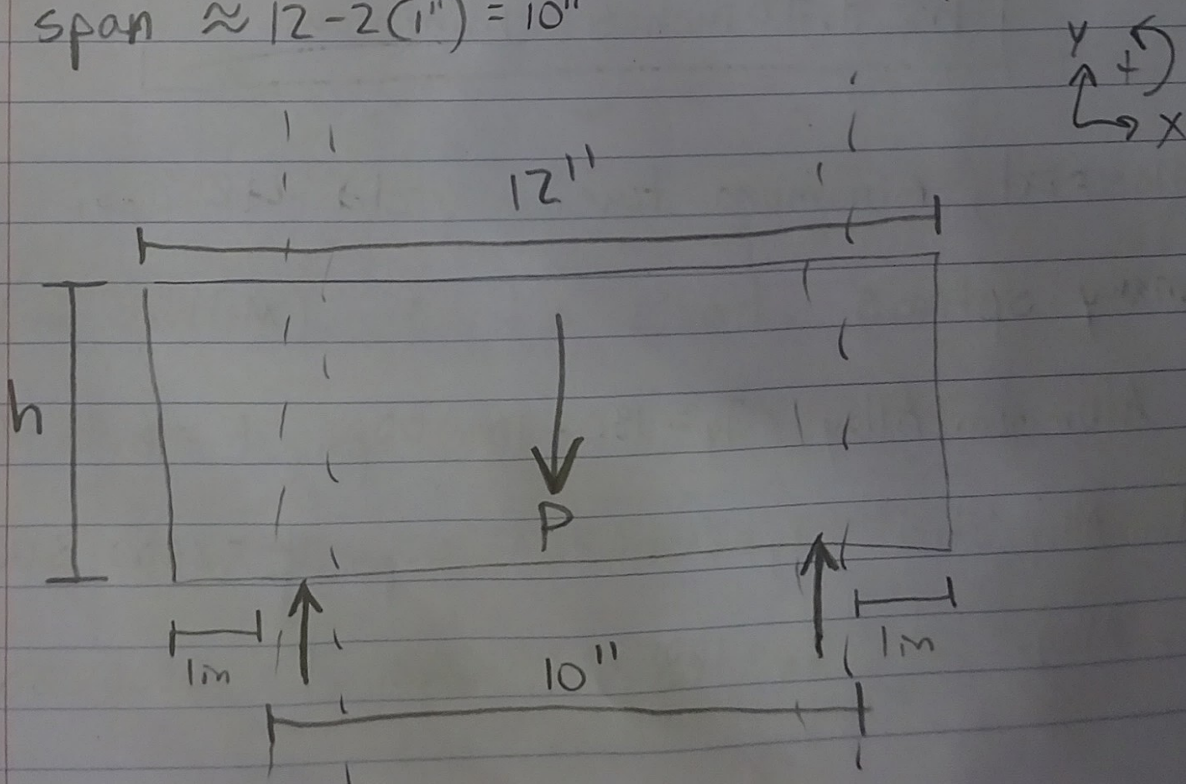
"Design, Manufacturing, and Testing of an Open-Source Universal Testing Machine for Hands-On Learning"
by Stell Demmel

Flange - Diameter = 1 1/2"

leave ~1 in of material around the flange cutout

Simple Beam Stress/Strength Analysis

known	unknown
max load 2kN	Crossbeam height
SF = 4	σ_{axial}
crosshead length = 12"	$\sigma_{bending}$
crosshead width = 1.5" + 2(1") = 3.5"	E (material properties)
span ≈ 12 − 2(1") = 10"	



lead screw selection

$\varnothing \approx 10mm \approx 1/4$ in

Assumption

calculated $\varnothing$ should be minor diameter of the lead screw (solid diameter)

$\varnothing_{min}$ for min diam $= 0.381$ in

Force per lead screw $= 1\text{ kN} = 1000\text{ N}\left(\frac{1\text{ lbf}}{4.45\text{ N}}\right)$
$\approx 225\text{ lbf} \times SF = 900\text{ lbf}$

Selection from roton.com

	bronze nut operating load	plastic nut operating load	minor diam
5/8 - 10	1900 lbf	950 lbf	0.483 in
or			
5/8 - 8	1900 lbf	950 lbf	0.457 in
or			
5/8 - 7	1900 lbf	950 lbf	0.438 in

Assumption

higher TPI will be better

Final Selection = ~~5/8 - 10 Acme lead screw~~

5/8 - 8 reason: McMaster-Carr does not offer any 5/8-10 lead screws

part # 98935A914

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Determine max Torque to provide the 2kN tension to the test sample

<u>known</u>

Tensile = 2kN

lead screw ϕ = 10mm

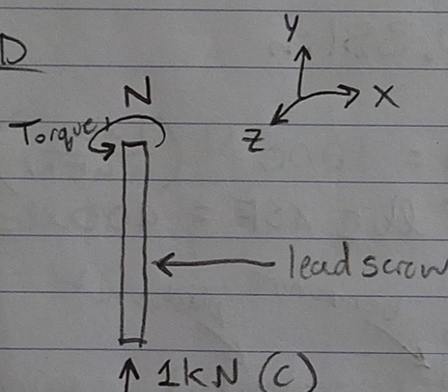
N = 0.0318 – 1.592 RPM

Force per lead screw = 1kN

<u>unknown</u>

max Torque

<u>FBD</u>



<u>Assumption</u>

treat each lead screw as a main power-transmitting shaft (S_s = 4,000 psi machinery's handbook).

$$D = \sqrt[3]{\frac{5.1\,T}{S_s}}$$

(machinery's handbook, metric, built-in SF)

T = N-mm   N = rpm   D = mm

S_s = N/mm²

$$S_s = 4{,}000\,\frac{\text{lbf}}{\text{in}^2}\left(\frac{1\,\text{in}}{25.4\,\text{mm}}\right)^2\left(\frac{4.448\,\text{N}}{1\,\text{lbf}}\right) = 27.58\ \text{N/mm}^2$$

$$T = \frac{D^3 S_s}{5.1}$$

$$T = \frac{(10\,\text{mm})^3(27.58\ \text{N/mm}^2)}{5.1} = \boxed{5408\ \text{N-mm}}$$

or

5.408 N-m

Determining range of rotational speed given the linear speed

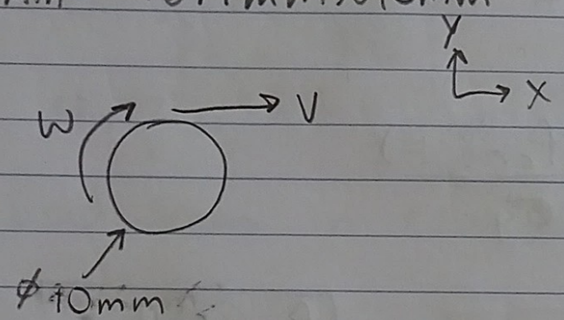
known

$v = 1 - 50 \, mm/min$

$\phi_{min} = 9.677mm \approx 10mm$

unknown

ω (rpm)



Assumption

diameter rounded from 9.677mm up to a flat 10mm

$$v = \frac{mm}{min} \qquad \omega = \frac{rev}{min}$$

$$1 \, rev = \pi \phi \, mm \rightarrow \frac{1 \, rev}{\pi \phi \, mm}$$

$$\omega \, (rpm) = v \left(\frac{mm}{min}\right) \left(\frac{1 \, rev}{\pi \, \phi \, mm}\right)$$

$$\omega_{low} = 1 \frac{mm}{min} \left(\frac{1 \, rev}{\pi (10mm)}\right) = 0.0318 \, rpm$$

$$\omega_{high} = 50 \frac{mm}{min} \left(\frac{1 \, rev}{\pi (10mm)}\right) = 1.592 \, rpm$$

$$\boxed{\omega_{range} = 0.0318 - 1.592 \, RPM}$$

Assuming $\phi \leq 1\tfrac{3}{4}'' \rightarrow \sigma_{y\,small},\ E_{small}$

$$\phi = \frac{4(0.a)(24\,in)}{\sqrt{\dfrac{\pi^2(26{,}500{,}000\,psi)(4)}{20{,}300\,psi}}}$$

$$\phi = 0.381\ in$$

$$3/8'' < 0.381in < 7/16'' \quad << 1\tfrac{3}{4}''$$

(load constraint)

$$\frac{\sigma_y}{SF} = \frac{P_{cr}}{A} \quad . \quad A = \frac{P_{cr}(SF)}{\sigma_y}$$

$$\pi\frac{d^2}{4} = \frac{P_{cr}(SF)}{\sigma_y} \rightarrow \phi = \sqrt{\frac{P_{cr}(SF)4}{\pi\sigma_y}}$$

$P_{cr} = 1kN$

$$\phi = \sqrt{\frac{(1{,}000N)(4)(4)}{\pi(140MPa)}} = 6.03mm$$

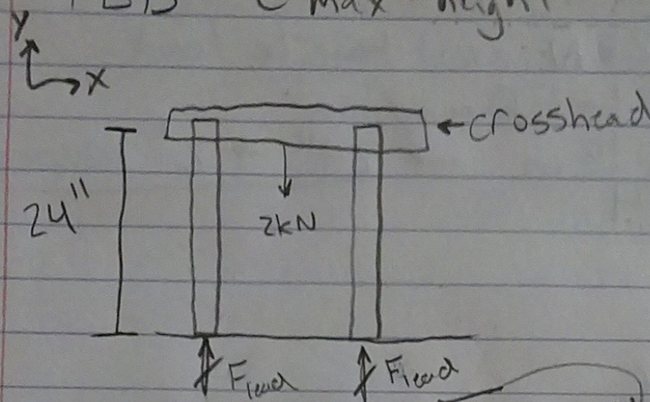
$$\phi = 6.03mm\left(\frac{1in}{2.54cm}\right)\left(\frac{1cm}{10mm}\right) = 0.237\ in < 1\tfrac{3}{4}''$$

$$\phi_{length} > \phi_{load}$$

$$\boxed{\text{minimum diameter} \approx 0.381\ in \quad \text{or} \approx 9.677mm}$$

$$0.381in\left(\frac{2.54cm}{1in}\right)\left(\frac{10mm}{1cm}\right) = 9.6774mm$$

FBD @ max height



$\Sigma F_y = 2F_{lead} - 2kN = 0$ $\quad \boxed{F_{lead} = +1kN}$

treat all end points as Fixed

$\downarrow$

recommended Effective Length Factor

$K = 0.9$

– mechanicalc.com

Lead screws in compression → buckling analysis

$$\sigma_{cr} = \frac{P_{cr}}{A} = \frac{\pi^2 E}{(K\frac{L}{r})^2}$$

L = unsupported length

r = radius of gyration

↳ for circle $r = \frac{\varnothing}{4}$

(mechanicalc.com)

$$\sigma_{cr} = \frac{\sigma_y}{SF}$$

(Length constraints)

$$\frac{\sigma_y}{SF} = \frac{\pi^2 E}{(K\frac{L}{r})^2} \rightarrow K\frac{L}{r} = \sqrt{\frac{\pi^2 E(SF)}{\sigma_y}}$$

$$\frac{L}{r} = \frac{\sqrt{\frac{\pi^2 E(SF)}{\sigma_y}}}{K} \rightarrow \frac{L}{\frac{\sqrt{\frac{\pi^2 E(SF)}{\sigma_y}}}{K}} = r$$

$$r = \frac{\varnothing}{4} = \frac{KL}{\sqrt{\frac{\pi^2 E(SF)}{\sigma_y}}} \rightarrow \varnothing = \frac{4KL}{\sqrt{\frac{\pi^2 E(SF)}{\sigma_y}}}$$