

Purpose: Determine the following for the main hoist lower block:

Rotate motor
Brake
Gearbox
Coupling
Attachment Plate

Define Units: $\text{fpm} := \frac{\text{ft}}{\text{min}}$ $\text{rpm} := \frac{2 \cdot \pi \cdot \text{rad}}{\text{min}}$ $\text{ksi} := 1000 \cdot \frac{\text{lbf}}{\text{in}^2}$ $\text{kips} := 1000 \cdot \text{lbf}$ $\text{tons} := 2 \text{kips}$

Design Inputs:

Maximum lifted load (plus hook):	$LL := 310 \cdot \text{tons} + 2.4 \cdot \text{kips}$	Reference 2 D-21 112-0500 10
Outside diameter of thrust bearing:	$d_{tb_out} := 12.50 \cdot \text{in}$	Attachment 3
Inside diameter of thrust bearing:	$d_{tb_in} := 8.031 \cdot \text{in}$	Attachment 3
Accelerating Torque Factor:	$k_t := 1.5$	Reference 1 Table 5.2.9.1.2.1-C
Service Class Factor:	$k_s := 1.1$	Reference 1 Table 5.2.9.1.2.1-E
Required Rotate Speed:	$\omega_{hook_req} := 2.0 \cdot \text{rpm}$	Reference 3 Section 5.7
Motor Speed:	$\omega_{motor} := 1735 \cdot \text{rpm}$	Attachment 1
Maximum allowable acceleration:	$\alpha_{max} := 0.015 \cdot \frac{\text{rad}}{\text{s}^2}$	Reference 3, Section 5.7
Inertia of high speed shaft:	$J_{hss} := 0.175 \cdot \text{lb} \cdot \text{ft}^2$	Attachment 1
Motor Power Reduction Factor (Altitude 5100 ft)	$F_{pr} := 0.97$	Attachment 1
Gearbox ratio:	$\text{ratio}_{gb} := 898$	Attachment 2
Acceleration time:	$t_{accel} := 15 \cdot \text{sec}$	
Efficiency of gearbox:	$\eta_{gb} := 0.88$	Attachment 2
Efficiency of thrust bearing:	$\eta_{tb} := 0.95$	Conservative estimate
Coefficient of friction of thrust bearing:	$\text{cof}_{tb} := 0.0035$	Attachment 3
Bearing Life	$L_{10_req} := 10000 \cdot \text{hr}$	Reference 3, Section 5.19

Calculations:

Determine the actual hook rotate speed, allowable to within 10% of desired per Ref. 1 Section 5.2.10.3:

$$\omega_{\text{hook_act}} := \frac{\omega_{\text{motor}}}{\text{ratio}_{\text{gb}}} = 1.93 \cdot \text{rpm}$$

$$\omega_{\text{hook_min_all}} := \omega_{\text{hook_req}} - \omega_{\text{hook_req}} \cdot 0.1 = 1.8 \cdot \text{rpm}$$

$$\omega_{\text{hook_max_all}} := \omega_{\text{hook_req}} + \omega_{\text{hook_req}} \cdot 0.1 = 2.2 \cdot \text{rpm}$$

$$\omega_{\text{hook_}} := \begin{cases} \text{"O.K."} & \text{if } \omega_{\text{hook_min_all}} \leq \omega_{\text{hook_act}} \leq \omega_{\text{hook_max_all}} \\ \text{"N.G."} & \text{otherwise} \end{cases}$$

$$\omega_{\text{hook_}} = \text{"O.K."}$$

Acceleration of hook rotate: $\alpha_{\text{hook}} := \frac{\omega_{\text{hook_act}}}{t_{\text{accel}}} = 0.013 \cdot \frac{\text{rad}}{\text{s}^2}$

$$\alpha_{\text{hook_}} := \begin{cases} \text{"O.K."} & \text{if } \alpha_{\text{hook}} \leq \alpha_{\text{max}} \\ \text{"N.G."} & \text{otherwise} \end{cases}$$

$$\alpha_{\text{hook_}} = \text{"O.K."}$$

Rotation completed when final speed is obtained: $\phi_{\text{comp}} := \frac{1}{2} \cdot \alpha_{\text{hook}} \cdot t_{\text{accel}}^2 = 1.52 \cdot \text{rad}$

$$\phi_{\text{comp}} = 86.94 \cdot \text{deg}$$

Mass Moment of Inertia of lifted cask:

$$WK2_{\text{cask}} := 1.24 \cdot 10^9 \cdot \text{lb} \cdot \text{in}^2$$

Reference 3,
Section 5.7

Mass moment of inertia:
(reflected to high speed shaft)

$$WK2_{\text{refl}} := WK2_{\text{cask}} \cdot \left(\frac{\omega_{\text{hook_act}}}{\omega_{\text{motor}}} \right)^2 + J_{\text{hss}} = 10.85 \cdot \text{lb} \cdot \text{ft}^2$$

Accelerating torque:

$$T_{\text{accel}} := \frac{WK2_{\text{refl}} \cdot \omega_{\text{motor}}}{t_{\text{accel}} \cdot (\eta_{\text{gb}} \cdot \eta_{\text{tb}})} = 4.89 \cdot \text{lbf} \cdot \text{ft}$$

Accelerating horsepower:

$$HP_{\text{accel}} := \left(\frac{T_{\text{accel}} \cdot \omega_{\text{motor}} \cdot k_s}{k_t} \right) = 1.184 \cdot \text{hp}$$

Mean diameter of thrust bearing:

$$d_{\text{tb}} := \frac{d_{\text{tb_out}} + d_{\text{tb_in}}}{2} = 10.27 \cdot \text{in}$$

Steady state torque:

$$T_{\text{ss}} := \frac{LL \cdot \frac{d_{\text{tb}}}{2}}{\text{ratio}_{\text{gb}} \cdot \eta_{\text{gb}}} \cdot \text{cof}_{\text{tb}} = 1.18 \cdot \text{lbf} \cdot \text{ft}$$

Free running horsepower:

$$HP_{\text{freerunning}} := T_{\text{ss}} \cdot \omega_{\text{motor}} = 0.390 \cdot \text{hp}$$

Total horsepower required:

$$HP_{\text{reqd}} := HP_{\text{freerunning}} + HP_{\text{accel}} = 1.57 \cdot \text{hp}$$