

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

Rotate motor  
Brake  
Gearbox  
Coupling  
Attachment Plate

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**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	LL := 310·tons	Reference 2
Hook Weight:	W <sub>hook</sub> := 2.4·kips	D-21 112-0500
Outside diameter of thrust bearing:	d <sub>tb_out</sub> := 12.50·in	Attachment 3
Inside diameter of thrust bearing:	d <sub>tb_in</sub> := 8.031·in	Attachment 3
Accelerating Torque Factor:	k <sub>t</sub> := 1.5	Reference 1 Table 5.2.9.1.2.1-C
Service Class Factor:	k <sub>s</sub> := 1.1	Reference 1 Table 5.2.9.1.2.1-E
Required Rotate Speed:	ω <sub>hook_req</sub> := 2.0·rpm	Reference 3 Section 5.7
Motor Speed:	ω <sub>motor</sub> := 1735·rpm	Attachment 1
Maximum allowable acceleration:	α <sub>max</sub> := 0.015 · $\frac{\text{rad}}{\text{s}^2}$	Reference 3, Section 5.7
Inertia of high speed shaft:	J <sub>hss</sub> := 0.175·lb·ft <sup>2</sup>	Attachment 1
Motor Power Reduction Factor (Altitude 5100 ft)	F <sub>pr</sub> := 0.97	Attachment 1
Gearbox ratio:	ratio <sub>gb</sub> := 898	Attachment 2
Acceleration time:	t <sub>accel</sub> := 15·sec	
Efficiency of gearbox:	η <sub>gb</sub> := 0.88	Attachment 2
Coefficient of friction of thrust bearing:	cof <sub>tb</sub> := 0.0035	Attachment 3
Bearing Life	L <sub>10_req</sub> := 10000·hr	Reference 3, Section 5.19

**References:**

Reference	Description	Revision
1	CMAA 70	2004
2	D-21124-0002	-
3	Equipment Specification for the NRF CSRF 310/75-Ton Overhead Crane	5
4	ACECO Engineering Procedures EP 1.2, Material Selection	0
5	AGMA 92-A96	1996
6	AGMA 6001	D97

**Computer programs used:** None

**Assumptions requiring later confirmation:** None

**Attachments:**

Attachment	Description
1	SEW Motor
2	Bonfiglioli Gearbox
3	QA Thrust Bearing
4	Falk Coupling

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

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:  $T_{\text{ss}} := \frac{\left[ (LL + W_{\text{hook}}) \cdot \frac{d_{\text{tb}}}{2} \right]}{\text{ratio}_{\text{gb}} \cdot \eta_{\text{gb}}} \cdot \text{cof}_{\text{tb}} = 1.18 \cdot \text{lbf} \cdot \text{ft}$

Determine efficiency of thrust bearing:

The Steady State Torque calculated without consideration of gearbox efficiency but only considering the c.o.f of the thrust bearing will be considered a 'loss' to the torque generated by the motor.

$$T_{\text{ss\_loss}} := \frac{\left[ (LL + W_{\text{hook}}) \cdot \frac{d_{\text{tb}}}{2} \right]}{\text{ratio}_{\text{gb}}} \cdot \text{cof}_{\text{tb}} = 1.04 \cdot \text{lbf} \cdot \text{ft}$$

Motor HP from selection below:  
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$$HP_{\text{act\_sel}} := 2.91 \cdot \text{hp}$$

Installed Torque from selection:

$$T_{\text{inst\_sel}} := \frac{HP_{\text{act\_sel}}}{\omega_{\text{motor}}} = 105.7 \cdot \text{lbf} \cdot \text{in}$$

Efficiency of thrust bearing

$$\eta_{\text{tb}} := \frac{T_{\text{inst\_sel}} - T_{\text{ss\_loss}}}{T_{\text{inst\_sel}}} = 0.882$$

Accelerating torque:

$$T_{\text{accel}} := \frac{WK2_{\text{refl}} \cdot \omega_{\text{motor}}}{t_{\text{accel}} (\eta_{\text{gb}} \cdot \eta_{\text{tb}})} = 5.26 \cdot \text{lbf} \cdot \text{ft}$$

Accelerating horsepower:

$$HP_{\text{accel}} := \left( \frac{T_{\text{accel}} \cdot \omega_{\text{motor}} \cdot k_s}{k_t} \right) = 1.27 \cdot \text{hp}$$

Free running horsepower:

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

Total horsepower required:

$$HP_{\text{reqd}} := HP_{\text{freerunning}} + HP_{\text{accel}} = 1.66 \cdot \text{hp}$$

## Rotate Motor Analysis

Selected motor: SEW DRE100L4

$$HP_{act} := 3.0 \cdot hp \cdot F_{pr} = 2.91 \cdot hp$$

Attachment 1

$$HP_{Accept} := \begin{cases} \text{"Okay"} & \text{if } HP_{act} > HP_{reqd} \\ \text{"N.G."} & \text{otherwise} \end{cases} \quad HP_{Accept} = \text{"Okay"}$$

Rotate horsepower reserve factor:

$$RF_n := \frac{HP_{act}}{HP_{reqd}} \quad RF_n = 1.75$$

Actual operating motor torque:

$$T_{act} := \frac{HP_{reqd}}{\omega_{motor}} = 60.46 \cdot \text{lbf} \cdot \text{in}$$

Installed Torque:

$$T_{inst} := \frac{HP_{act}}{\omega_{motor}} = 105.7 \cdot \text{lbf} \cdot \text{in}$$

Peak motor torque:

$$T_{peak} := \frac{HP_{act}}{\omega_{motor}} \cdot 150\% = 158.6 \cdot \text{lbf} \cdot \text{in}$$

## Brake Analysis

Required Maximum Brake Torque:  
(Reference 3, Section 5.15)

$$T_{brake\_max} := T_{inst} \cdot 20\% = 21.14 \cdot \text{lbf} \cdot \text{in}$$

Selected Brake: SEW BE02

$$T_{brake} := 20 \cdot \text{lbf} \cdot \text{in}$$

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$$Brake_{Accept} := \begin{cases} \text{"Okay"} & \text{if } T_{brake\_max} > T_{brake} \\ \text{"N.G."} & \text{otherwise} \end{cases} \quad Brake_{Accept} = \text{"Okay"}$$

Note: The selected brake is the smallest available for the motor being utilized. This brake, although larger than allowed by Reference 3, does not actually contribute to the deceleration of the load. The deceleration will be programmed into the variable frequency drive for a gradual uniform stop. The brake will only be utilized as a holding brake.