Application Engineering- Overhauling Loads

TABLE OF SYMBOLS

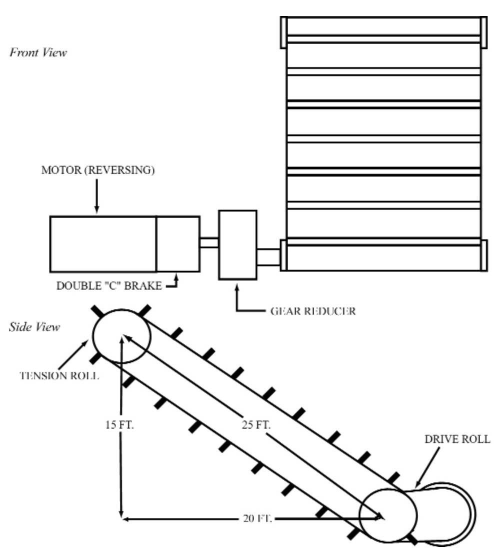
W_L	Weight of overhauling load
W	Total weight of load acting at motor brake
V_L	Linear velocity of load subjected to linear motion
Θ	Angle of incliination for overhauling load
WK^2_T	Total rotational moment of inertia acting at motor brake
N_L	Rotational speed of load
N_B	Rotational speed of brake
T_O	Torque required at brake to hold overhauling load
T_{BM}	Minimum brake torque to stop and hold application
T_{SB}	Torque rating of selected brake
t_{SB}	Stopping time of application using selected brake
TDS	Total distance travelled by linear load during stop
HPS	Horsepower seconds per stop
ASM	Allowable stops per minute
RTC	Rated thermal capacity of brake

The procedure for sizing a brake in an application subjected to overhauling loads has four steps:

I. Determine rotational moment of inertia acting at motor brake.
II. Determine minimum torque required to stop and hold system.
III. Calculate system performance using selected brake.
IV. Evaluate system performance.

Before starting this process, the following application information is needed to conduct the sizing calculations:

- A detailed sketch of the brake-motor application.
- Motor data, including horsepower rating, speed (rpm), rotational inertia (lb-ft^2) and NEMA frame size.
- Rotational inertia (lb-ft^2) of all system components acting at the brake.
- Rotational speed (rpm) of all system components acting at the brake.
- Weight (lbs) and velocity (ft/min) of loads subjected to linear motion.
- Angle of inclination if overhauling load is not acting vertically.
- Cycle rate of system (stops/min).



Example: Application Information for Bucket Conveyor

Motor Data:

Horsepower Rating	5 HP
Speed	1,760 RPM
Rotational Inertia	0.30 lb-ft^2
NEMA Frame Size	184 TC

Rotational Inertia of All Active System Components:

Motor Brake Data:

Rotational Inertia	0.11 lb-ft^2

Gear Reducer Data:

Gear Reduction Ratio	50:1
Gear Reducer Inertia	0.14 lb-ft^2

Drive Roll Data:

Roll Diameter	0.955 ft
Roll Length	2.5 ft
Rotational Inertia	99.338 lb-ft^2
Tension Roll Data	Same as Drive Roll

Rotational Speed of All Components Acting at Brake:

Motor	1,760 RPM
Brake	1,760 RPM
Gear Reducer	1,760 RPM (in)
	35.2 RPM (out)
Drive Roll	35.2 RPM
Tension Roll	35.2 RPM

Weight and Velocity of Loads Subjected to Linear Motion:

For this example, we will use the following conveyor data:

Empty weight of conveyor belt (per foot basis)	15 lbs
Total length of conveyor belt	53 ft
Empty weight of conveyor bucket	20 lbs
Spacing of buckets on conveyor	1 ft
Total number of buckets on conveyor	52
Load capacity of each bucket	75 lbs

$$W_C = (53\text{ ft})(15\text{ lb/ft}) + (52)(20\text{ lbs}) = 1{,}835\text{ lbs}$$

$$W_L = (0.5)(52)(75\text{ lbs}) = 1{,}950\text{ lbs}$$

**The W_L calculation assumes that only half of the buckets will carry a load at any given instant.*

$$W = W_C + W_L = 3{,}785\text{ lbs}$$

(For velocity calculations)

$$V_L = (35.2\text{ rev/min})(0.955\text{ ft})\,\pi = 105.6\text{ ft/min}$$

Angle of Inclination:

$$Ø = SIN^{-1}\left(\frac{H}{L}\right) = SIN^{-1}\left(\frac{15}{25}\right) = 36.87^{o}$$

$$SIN\ Ø = 0.600$$

Then: (For weight calculations)
Cyclic Rate of System:
Maximum of 2 stops/minute.
Using the application information, select a brake for this system.

Application Engineering- Overhauling Loads

I. DETERMINE ROTATIONAL MOMENT OF INERTIA ACTING AT MOTOR BRAKE

Known Quantities:

Motor	0.3000 lb-ft2
Brake	0.1100 lb-ft2
Gear Reducer	0.1400 lb-ft2

(A) Contribution from rotary load at different speed than brake shaft:

(For Drive Roller)

$$WK^2_{DR} = WK^2_{DRD}\left(\frac{N_L}{N_B}\right)^2 = (99.338 \text{ lb-ft}^2)\left(\frac{35.2}{1760}\right)^2 = 0.0397 \text{ lb-ft}^2$$

(For Tension Roller)

$$WK^2_{TR} = WK^2_{TRD}\left(\frac{N_L}{N_B}\right)^2 = (99.338 \text{ lb-ft}^2)\left(\frac{35.2}{1760}\right)^2 = 0.0397 \text{ lb-ft}^2$$

**This assumes that there is no slippage between conveyor belt and rollers.*

(B) Contribution from loads subjected to linear motion:

$$WK^2_L = W\left(\frac{V_L}{2\pi N_B}\right)^2 = (3{,}785 \text{ lbs})\left(\frac{105.6}{2\pi 1760}\right)^2 = 0.3452 \text{ lb-ft}^2$$

Then:

$$WK^2_T = WK^2_M + WK^2_B + WK^2_{GR} + WK^2_{DR} + WK^2_{TR}$$

$$WK^2_T = 0.9746 \text{ lb. ft.}^2$$

II. DETERMINE MINIMUM TORQUE REQUIRED TO STOP AND HOLD SYSTEM

(A) Calculate overhauling torque of fully loaded conveyor belt:

$$T_O = \frac{(0.158)(\mathrm{SIN}(\Theta))(W_L)(V_L)}{N_B}$$

$$T_O = \frac{(0.158)(0.600)(1950 \text{ lb})(105.6 \text{ ft/min})}{1760 \text{ RPM}} = 11.092 \text{ lb. ft.}$$

(B) Calculate minimum brake torque:

$$T_{BM} = \frac{(WK^2_T)(N_B)}{308t} + T_O$$

$$T_{BM} = \frac{(0.9746 \text{ lb. ft.}^2)(1760)}{(308)(1)} + 11.092 \text{ lb. ft.}$$

$$T_{BM} = 5.569 \text{ lb. ft.} + 11.092 \text{ lb. ft.} = 16.661 \text{ lb. ft.}$$

Please note that the maximum stopping time should not exceed one second.

Therefore, we must select a brake with a torque rating of at least 16.661 lb-ft which fits on a NEMA 184 TC frame size.

Selected Brake Data:

Dings Model Number	4-72025-46
Enclosure Type	NEMA 4
Brake Style	Double "C" Face
Rated Thermal Capacity	12
Rotational Inertia	0.1097 lb-ft^2

III. CALCULATE SYSTEM PERFORMANCE USING SELECTED BRAKE

(A) Stopping time calculation:

$$t_{SB\uparrow} = \frac{(WK^2_T)(N_B)}{(308)(T_{SB} + T_O)} = \frac{(0.9746 \text{ lb. ft.}^2)(1760)}{(308)(25+11.092)} = 0.154 \text{ sec}$$

$$t_{SB\downarrow} = \frac{(WK^2_T)(N_B)}{(308)(T_{SB} - T_O)} = \frac{(0.9746 \text{ lb. ft.}^2)(1760)}{(308)(25-11.092)} = 0.400 \text{ sec}$$

(B) Travel distance during stop calculations:

$$TDS_\uparrow = \frac{0.5\, V_L\, t_{SB\uparrow}}{60} = \frac{(0.5)(105.6 \text{ ft/min})(0.154\text{s})}{60} = 0.136 \text{ ft}$$

$$TDS_\downarrow = \frac{0.5\, V_L\, t_{SB\downarrow}}{60} = \frac{(0.5)(105.6 \text{ ft/min})(0.400\text{s})}{60} = 0.352 \text{ ft}$$

(C) Thermal requirement calculations:

(without overhauling load)

$$\text{H.P. Sec/Stop} = WK^2_T\left(\frac{N_B}{1800}\right)^2 = (0.9746 \text{ lb. ft.}^2)\left(\frac{1760}{1800}\right)^2 = 0.932 \text{ HPS/Stop}$$

(with ascending overhauling load)

$$\text{H.P. Sec/Stop}_{O\uparrow} = \text{H.P. Sec/Stop}\left(\frac{T_{SB}}{T_{SB} + T_O}\right)$$

$$= (0.932)\left(\frac{25}{25+11.092}\right) = 0.646 \text{ HPS/Stop}_{O\uparrow}$$

(with descending overhauling load)

$$\text{H.P. Sec/Stop}_{O\downarrow} = \text{H.P. Sec/Stop}\left(\frac{T_{SB}}{T_{SB} - T_O}\right)$$

$$= (0.932)\left(\frac{25}{25-11.092}\right) = 1.675 \text{ HPS/Stop}_{O\downarrow}$$

Since the worst case scenario is a descending overhauling load, it will be used to determine allowable stops:

(D) Allowable stops calculation:

$$ASM = \frac{RTC}{\left(\frac{HPS_{O\uparrow}}{MIN}\right)} = \frac{12}{1.675} = 7.16\ \frac{STOPS}{MIN}$$

IV. EVALUATE SYSTEM PERFORMANCE

(1) Stopping time of system is less than one second so brake torque is adequate.

(2) Allowable stops per minute is more than three times the specified number of two, so rated thermal capacity is adequate.

Therefore, we can conclude that the brake will function as intended.