FREQROL

MITSUBISHI
TRANSISTORIZED INVERTER

TECHNICAL NOTE

No. 25

CAPACITY SELECTION FOR LIFTING OPERATION

MITSUBISHI

CONTENTS

APPENDICES

CHAPTER 1 DEFINITION OF LIFTING OPERATION AND POINTS ABOUT CAPACITY SELECTION

1.1 Definition of Lifting Operation

Operation patterns are largely classified by operation time into constant-speed long operation and repeated short operation. The former is referred to as "continuous operation" and the latter as "cyclic operation", and lifting operation belongs to cyclic operation. A feature of lifting operations is that the load characteristic differs with the direction of rotation. That is, there are two modes: positive load (generally during lifting) and negative load (generally during lowering). For lifting operation, it is especially important to examine regenerative energy under negative load.

<Data required for selection> **Technical Note No. 22 "Capacity Selection: Data Section".**

1.2 Points about Capacity Selection

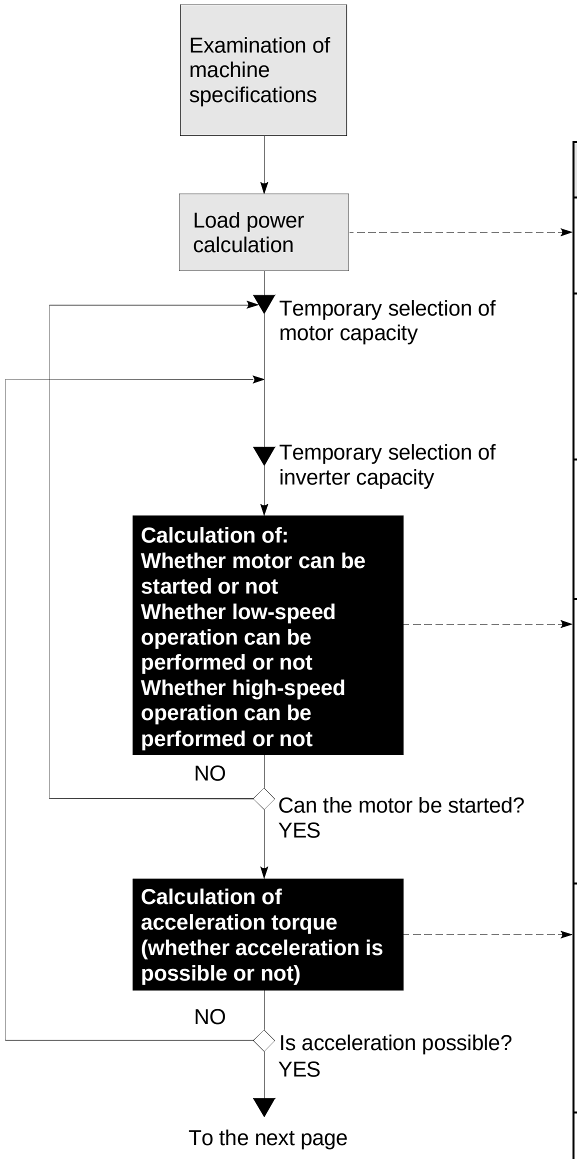
(1) Regenerative energy must be handled.
Under negative load, the motor is rotated by the load. Basically, the motor is driven (rotated at more than the synchronous speed) by the energy of the load and its power is returned to the inverter. To handle this regenerative energy, the use of a brake unit or power return converter must be examined.

(2) Large starting torque is needed at a low frequency.
To prevent the load from slipping down due to insufficient starting torque of the motor at the start of lifting (positive load), it is necessary to select the motor and inverter which provide sufficient starting torque. Particularly, the optimum inverter (open-loop) is the FR-A500 series inverter which uses advanced magnetic flux vector control to allow low-speed torque to be increased.

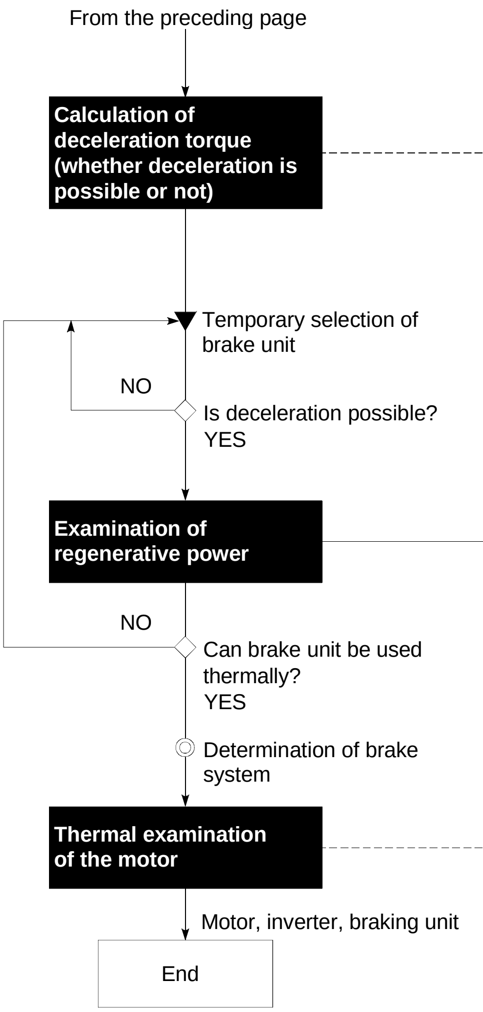
(3) Mechanical safety brake is required.
A mechanical safety brake must be used with the lifter to hold the load while stopped.

CHAPTER 2 SELECTION PROCEDURE

2.1 Selection Flowchart



Selection Outline	Refer To Page
Required power (P_L) $= \frac{W \times V}{6120 \times \eta}$ [kW]	5
(1) Select the motor capacity which is more than the required power. (2) Increase the motor capacity to increase starting torque.	5 5
(1) Select the inverter equivalent to the motor capacity. (2) Increase the inverter capacity to increase acceleration torque.	5
(1) Motor starting torque T_{MS} > load torque at start (T_{LS}) (2) Motor torque at low speed $T_M \times \alpha_m \times \delta$ > load torque (T_L) (3) Motor torque at high speed $T_M \times \alpha_m$ > load torque (T_L)	5 6 6
Acceleration torque $T_a = \frac{\sum GD^2 \times N}{38.2 \times ta}$ [N•m] **375** **[kgf•m]** Ta : Acceleration torque ta : Acceleration time [s]	7
Examination of whether acceleration can be made or not $\frac{Ta_{max}}{T_M} < \alpha_a$ α_a : Acceleration torque coefficient	8



Selection Outline	Refer To Page
Deceleration torque $Td = \frac{\Sigma GD^2 \times N}{38.2 \times t_d}$ [N•m] **375** **[kgf•m]** Td : Deceleration torque t_d : Deceleration time [s]	8
$\frac{Td_{max}}{T_M} < \beta_{min}$ β_{min}: Brake torque coefficient (Temporarily select the brake unit and power return built-in inverter in accordance with the Technical Note No. 22.	8
(1) Check the short-time permissible power. $W_{INV} < W_{RS}$	9, 10
(2) Check the continuous permissible power. $W_{INV} \times t / tc < W_{RC}$ W_{INV} : Power returned to the inverter t : Time when negative load torque is applied [s] tc : Time of whole 1 cycle [s]	9, 10
Motor equivalent current value $I_{MC} = \sqrt{\frac{\Sigma(In^2 \times tn)}{\Sigma(Cn \times tn)}} < 100$ [%]	12, 13

Note: The units are in the SI systems of units.
The half-tone screen indicates the gravitational systems of units.

2.2 Specification Symbols Related to the Load and Operation Required for Selection

Table 2.1 Specification Symbol/Unit List

Specifications		Symbol	SI Systems of Units	Gravitational Systems of Units
Machine side specifications	Required power	P_L	kW	kW
	Motor capacity	P_M	kW	kW
	Number of motor poles	P	—	—
	Motor speed	N	r/min	rpm
	Frequency	f	Hz	Hz
	Moving velocity	V	m/min	m/min
	Load weight	W	kgf	kgf
	Machine efficiency	η	—	—
	Friction coefficient	μ	—	—
	Load torque converted into the equivalent value at the motor shaft	T_L	N•m	kgf•m
	Load torque at start converted into the equivalent value at the motor shaft	T_{LS}	N•m	kgf•m
	Load GD^2 converted into the equivalent value at the motor shaft	GD^2_L	kgf•m^2	kgf•m^2
	GD^2 of mechanical brake converted into the equivalent value at the motor shaft	GD^2_B	kgf•m^2	kgf•m^2
	Cycle time (1 cycle)	tc	s	s
	Time in each operation zone	tn	s	s
	Acceleration time	ta	s	s
	Deceleration time	td	s	s
	Acceleration	Acc	m/s^2	m/s^2
Specifications used for examination	Rated motor speed	N_M	r/min	rpm
	Rated motor torque	T_M	N•m	kgf•m
	Maximum motor starting torque	T_{MS}	N•m	kgf•m
	Acceleration torque	Ta	N•m	kgf•m
	Deceleration torque	Td	N•m	kgf•m
	Load torque factor	TF	%	%
	Motor GD^2	GD^2_m	kgf•m^2	kgf•m^2
	Short-time maximum torque coefficient	α_m	—	—
	Maximum starting torque coefficient	α_s	—	—
	Linear acceleration torque coefficient	α_a	—	—
	Brake torque coefficient (general term)	β	—	—
	Heat coefficient	σ	—	—
	Cooling coefficient	C	—	—
	Motor current	I	%	%
	Motor equivalent current value	I_{MC}	%	%
Regenerative power	Average power absorbed by the motor	W_M	W	W
	Average power returned to the inverter	W_{INV}	W	W
	Average power returned from the machine	W_{MECH}	W	W
	Continuous permissible power of the brake unit	W_{RC}	W	W
	Short-time permissible power per operation of the brake unit	W_{RS}	W	W
Stopping accuracy	Stopping time	tb	s	s
	Stopping distance	S	mm	mm
	Stopping accuracy	$\Delta\varepsilon$	mm	mm

CHAPTER 3 SELECTION PROCEDURE

3.1 Calculation of Load Power

The general way of finding the Power required for the load (P_L) is by the following formula:

$$\boxed{P_L = \frac{W \times V}{6120 \times \eta} \text{ [kW]}}$$

where

W : Load weight (moving object weight) [kgf]

V : Moving velocity [m/min]

η : Machine efficiency

3.2 Temporary Selection of Motor and Inverter

(1) Temporary selection of motor capacity
Temporarily select the motor capacity (P_M) larger than the required power (P_L).

$$\boxed{\text{Temporarily selected motor capacity } (P_M) \geq P_L \times \alpha p \text{ [kW]} \quad \alpha p\text{: 0.5 to 2.0}}$$

When V/F control is selected or GD^2 is large, for example, it is recommended to temporarily select the coefficient of 1.0 or more as αp.
If the motor speed (N) during rated load drive is less than the rated motor speed (N_M), the motor torque cannot be utilized to the maximum and the motor capacity increases as indicated by formula (3.2):

$$\boxed{\text{Temporarily selected motor capacity } (P_M) \geq P_L \times \alpha p \times N_M/N \text{ [kW]}}$$

(2) Temporary selection of inverter capacity
Temporarily select the inverter capacity identical to the temporarily selected motor capacity.

$$\boxed{\text{Temporarily selected inverter capacity } (P_{INV}) \geq \text{temporarily selected motor capacity } (P_M) \text{ [kW]}}$$

When the acceleration torque required is expected to be greater than 1.4 times of the stationary load torque, temporarily select the inverter capacity one rank higher than the motor capacity.

3.3 Examination of Whether the Motor Can be Started or Not

As the inverter-driven motor is accelerated with the current held within the overcurrent limit (150%, 1 minute) of the inverter at start and during acceleration, the starting torque and acceleration torque are smaller than those in direct-on line starting with a commercial power supply. Especially during lifting, the motor torque must be made larger than the load torque to prevent the load from slipping down when the mechanical holding brake is released.

$$\boxed{\begin{array}{l} T_{MS} > T_{LS} \\ T_{MS} = T_M \times \alpha s \times \delta \end{array}}$$

T_{MS} : Maximum motor starting torque
Short-time maximum motor torque × δ at the starting frequency
(Refer to Technical Note No. 22.)

αs : Maximum starting torque coefficient

δ : Heat coefficient (Refer to Technical Note No. 22)

T_{LS} : Load torque at start
Under the influence of static friction, torque for starting motion in a static state is larger than the stationary load torque. Determine this value after making a full examination of the mechanical system.
Under regenerative load, make calculation by setting the machine efficiency (η) to 1 and the friction coefficient (μ) to 0 to take safety into consideration.

3.4 Examination of Whether Low-speed and High-Speed Operations Can Be Performed or Not

(1) Whether low-speed operation can be performed or not

Low-speed operation is determined by the minimum frequency f_{min} and required stopping accuracy of the operation pattern.
When f_{min} is less than 6Hz, the lifting torque characteristic reduces remarkably and cannot be used practically. In this case, reconsider the motor capacity, machine gearbox reduction ratio, etc. so that f_{min} is within the range of 6 to 120Hz.

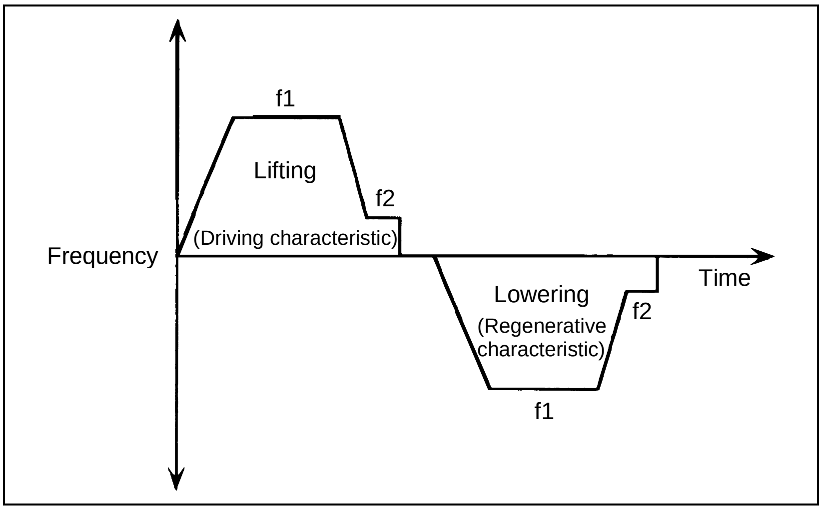


Fig. 3.1 Operation Pattern

Suppose that f_2 (low-speed running frequency during lifting) ≥ 6Hz.
Low-speed operation can be performed if the following condition is satisfied:

$$\boxed{T_M \times \alpha_m \times \delta > T_L}$$

α_m : Short-time maximum torque coefficient
T_{Lmax} : Maximum. load torque [N•m] [kgf•m]
Under regenerative load, make calculation by setting the machine efficiency (η) to 1 and the friction coefficient (μ) to 0 to take safety into consideration.

(2) Whether high-speed operation can be performed or not

When the maximum frequency is 60Hz or more, high-speed operation can be performed if the following condition is satisfied at the maximum frequency:

$$\boxed{T_M \times \alpha_m > T_L}$$

α_m : Short-time maximum torque coefficient at f_{max}

3.5 Examination of Whether Acceleration/Deceleration Is Possible or Not

When the motor is accelerated by the inverter, there are two modes: linear acceleration and non-linear acceleration. For an application which requires one-cycle time to be kept or for a lift, use linear acceleration for examination.
Deceleration torque is defined as [-Td] since it is a negative load relative to acceleration torque. The torque required for deceleration is found by adding load torque to the deceleration torque, check whether the temporarily selected combination of motor and inverter provides sufficient brake torque or not.

(1) Acceleration time (ta)

Represents a period of time required to accelerate from a stop state to the maximum motor speed (N_{max}) (maximum moving velocity (V_{max})).

$$ta = \frac{V_{max}}{60 \times Acc} \quad [s]$$

Note

Acceleration (Acc) indicates that velocity increases with time when an object begins to move and velocity decreases with time when that object stops. Thus, it is said there is acceleration when velocity varies with time and the magnitude of acceleration is represented by the variation of velocity per second. If this velocity increases by 9.8m per second then this acceleration is represented by G, 1G = 9.8m/s^2.

(2) Acceleration torque (Ta)

Acceleration torque (Ta) is found by the following formulas:

<SI systems of units> <Gravitational systems of units>

$$Ta = \frac{\sum GD^2 \times N_{max}}{38.2 \times ta} \ [N\bullet m] \qquad Ta = \frac{\sum GD^2 \times N_{max}}{375 \times ta} \ [kgf\bullet m]$$

$\sum GD^2$: Sum total of GD^2 converted into the equivalent value at the motor shaft

$= GD^2_M + GD^2_B + GD^2_L$

(Motor) (Brake) (Load)

(3) Deceleration time (td)

$$td = \frac{V_{max}}{60 \times Acc} \ [s]$$

(4) Deceleration torque (Td)

Deceleration torque (Td) is found by the following formulas:

<SI systems of units> <Gravitational systems of units>

$$Td = \frac{\sum GD^2 \times N_{max}}{38.2 \times td} \ [N\bullet m] \qquad Td = \frac{\sum GD^2 \times N_{max}}{375 \times td} \ [kgf\bullet m]$$

(5) Torque applied to the motor in each operation region

When the operation pattern is assumed to be as shown in Fig. 3.2, find the torque applied to the motor in each of the operation regions 1) to 8).

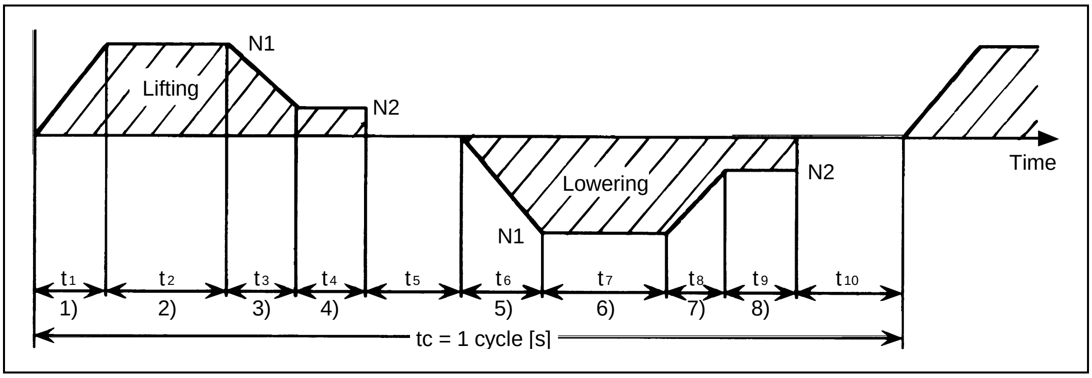


Fig. 3.2 Operation Pattern

The torque applied to the motor in each operation region during vertical lift operation is as follows:

	Region	Torque applied to the motor [N•m]	SI systems of units [N•m] Gravitational systems of units [kgf•m]
Lifting	1)	$T_{aup} = T_{a1} + T_{Uup} + Tfr_{up}$	
	2)	$T_{LU} = T_{Uup} + Tfr_{up}$	
	3)	$T_{dup} = -T_{d1} + T_{Uup} + Tfr_{up}$	
	4)	$T_{LU} = T_{Uup} + Tfr_{up}$	
Lowering	5)	$T_{adn} = T_{a2} + T_{Udn} + Tfr_{dn}$	
	6)	$T_{LD} = T_{Udn} + Tfr_{dn}$	
	7)	$T_{ddn} = -T_{d2} + T_{Udn} + Tfr_{dn}$	
	8)	$T_{LD} = T_{Udn} + Tfr_{dn}$	

Under regenerative load, calculate T_{uup} and T_{udn} with negative signs.

<SI systems of units>

Where:

Unbalance torque during lifting (lowering):

$$T_{Uup} = (T_{Udn}) = \frac{W \times g \times \Delta S \times 10^{-3}}{2 \times \pi \times \eta} \quad [\text{N•m}]$$

Friction torque of drive section during lifting (lowering):

$$Tfr_{up} = (Tfr_{dn}) = \frac{\mu \times W \times g \times \Delta S \times 10^{-3}}{2 \times \pi \times \eta} \quad [\text{N•m}]$$

Machine efficiency of drive section: η
Moving amount per motor revolution: ΔS [mm]
Load weight: W
Acceleration of gravity: g

Under regenerative load, make calculation by setting η to 1 and μ to 0 to take safety into consideration.

Acceleration torque during lifting :Ta_1 [N•m]
Acceleration torque during lowering :Ta_2 [N•m]
Deceleration torque during lifting :Td_1 [N•m]
Deceleration torque during lowering :Td_2 [N•m]

< Gravitational systems of units>

Where:

Unbalance torque during lifting (lowering):

$$T_{Uup} = (T_{Udn}) = \frac{W \times g \times \Delta S \times 10^{-3}}{2 \times \pi \times \eta} \quad [\text{kgf•m}]$$

Friction torque of drive section during lifting (lowering):

$$Tfr_{up} = (Tfr_{dn}) = \frac{\mu \times W \times g \times \Delta S \times 10^{-3}}{2 \times \pi \times \eta} \quad [\text{kgf•m}]$$

Machine efficiency of drive section: η
Moving amount per motor revolution: ΔS [mm]
Load weight: W

Under regenerative load, make calculation by setting η to 1 and μ to 0 to take safety into consideration.

Acceleration torque during lifting :Ta_1 [kgf•m]
Acceleration torque during lowering :Ta_2 [kgf•m]
Deceleration torque during lifting :Td_1 [kgf•m]
Deceleration torque during lowering :Td_2 [kgf•m]

(6) Whether acceleration is possible or not

Make sure that the temporarily selected motor output torque is larger than the torque required for acceleration.

The maximum torque (Ta_{max}) required for acceleration is either of Ta_{up} in region 1) and Ta_{dn} in region 5), which is larger.

Motor output torque		Torque required for acceleration
$T_M \times \alpha a$	>	Ta_{max}

Linear acceleration torque coefficient αa is as follows:

$$\frac{Ta_{max}}{T_M}$$

Ta_{max} : Max. torque required for acceleration
T_{Lmax} : Maximum value of load torque converted into the equivalent value at the motor shaft
T_M : Rated motor torque
αa : Linear acceleration torque coefficient (refer to Technical Note No. 22)

Note: Regenerative acceleration is made when $Ta_{up} < 0$ and $Ta_{dn} < 0$. In this case, the maximum torque required for regeneration is judged by whether deceleration is possible or not. Hence, the judgment of whether acceleration is possible or not is not needed here.

(7) Whether deceleration is possible or not

Make sure that the brake torque developed by the temporarily selected motor-inverter combination is larger than the torque required for deceleration.

The maximum torque Td_{max} required for deceleration is either of Td_{up} in region 3 and Td_{dn} in region 7, which is smaller.

Torque needed for deceleration		Brake torque of temporarily selected motor-inverter combination
$\lvert Td_{max} \rvert$	$<$	$T_M \times \beta_{min}$

The deceleration torque coefficient β at this time is:

$$\frac{\lvert Td_{max} \rvert}{T_M}$$

Td_{max} : Maximum torque required for deceleration
T_M : Rated motor torque
β_{min} : Minimum value of deceleration torque coefficient
(Refer to Technical Note No. 22.)

Note: Driving deceleration is made when $Td_{up} > 0$ and $Ta_{dn} > 0$. In this case, the maximum torque required for driving is judged by whether acceleration is possible or not. Hence, the judgment of whether deceleration is possible or not is not needed here.

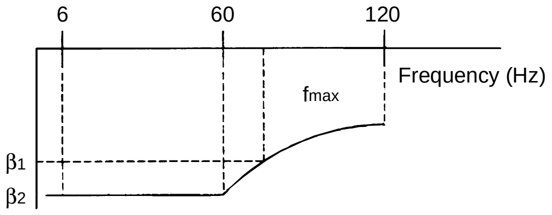
If the above formula cannot be satisfied, increase the braking torque of the motor-inverter combination by the following means. (Refer to Technical Note No. 22.)

(a) Use an external brake resistor or brake unit.
(b) Use the power return built-in inverter (FR-A201).

Note

How to find the deceleration torque coefficient

For the deceleration torque coefficient (β_{min}), select the smaller value of the torque coefficient β_2 at 6Hz and the torque coefficient β_1 at the maximum operating frequency (f_{max}) in the over-60Hz region.



3.6 Examination of Regenerative Power (Thermal Examination of Brake Unit)

(1) Regenerative power in each operation zone

Assuming that the operation pattern is as shown in Fig. 3.2, find the average regenerative power returned to the inverter (W_{INV}) during one-cycle time (tc) and make sure that the resultant value is within the power consumption limit of the brake (the continuous permissible power of the braking unit (W_{RC}) and the short-time permissible power per operation of the braking unit (W_{RS})) to determine whether the braking unit can be used thermally or not.

Torque and regenerative power (power in the negative power zone) in each operation zone during lifting operation are as follows:

<SI systems of units>

Region	Regenerative Power [W]
1)	$W_1 = 0.1047 \times \frac{N_1}{2} \times T_{aup}$
2)	$W_2 = 0.1047 \times N_1 \times T_{LU}$
3)	$W_3 = 0.1047 \times \frac{N_1 + N_2}{2} \times T_{dup}$
4)	$W_4 = 0.1047 \times N_2 \times T_{LU}$
5)	$W_6 = 0.1047 \times \frac{N_1}{2} \times T_{adn}$
6)	$W_7 = 0.1047 \times N_1 \times T_{LD}$
7)	$W_8 = 0.1047 \times \frac{N_1 + N_2}{2} \times T_{ddn}$
8)	$W_9 = 0.1047 \times N_2 \times T_{LD}$

<Gravitational systems of units>

Region	Regenerative Power [W]
1)	$W_1 = 1027 \times \frac{N_1}{2} \times T_{aup}$
2)	$W_2 = 1027 \times N_1 \times T_{LU}$
3)	$W_3 = 1027 \times \frac{N_1 + N_2}{2} \times T_{dup}$
4)	$W_4 = 1027 \times N_2 \times T_{LU}$
5)	$W_6 = 1027 \times \frac{N_1}{2} \times T_{adn}$
6)	$W_7 = 1027 \times N_1 \times T_{LD}$
7)	$W_8 = 1027 \times \frac{N_1 + N_2}{2} \times T_{ddn}$
8)	$W_9 = 1027 \times N_2 \times T_{LD}$

(2) Thermal examination

Calculate the average power returned from the load [W_{MECH}] by the following formula:

$$\boxed{W_{MECH} = \frac{\left|\Sigma(W_n \times t_n)\right|}{\Sigma t_n} \text{ [W]}}$$

(Refer to Fig. 3.2)

Note that $W_n \times t_n$ and tn are calculated for only the regions where power becomes negative.
The average power returned to the inverter during one cycle (W_{INV}) is:

$$\boxed{W_{INV} = W_{MECH} \times 0.9 \text{ [W]}}$$

Here, the average power returned to the inverter (W_{INV}) during single-cycle operation time (tc) is compared with the power absorbed by the brake resistor (W_{RC} and W_{RS}) for analysis:

$$\boxed{W_{INV} \times \frac{\Sigma t_n}{tc} < W_{RC}}$$

where W_{RC} : Continuous permissible power of the brake unit (refer to Chapter 3 Braking Capability Data in Technical Note 22.)

Note that $W_n \times t_n$ and tn are calculated for only the regions where power becomes negative.

$$\boxed{W_{INV} < W_{RS}}$$

where W_{RS} : Short-time permissible power per operation of the brake unit (refer to Chapter 3 Braking Capability Data in Technical Note 22.)

Note: Also perform the following check on the zones where the severest regenerative operation is performed (especially zones 6 and 7 in Fig. 3.2):

$$\boxed{W_n \times 0.9 < W_{RS}}$$

where Wn : Power in the corresponding zone [W]
W_{RS} : Short-time permissible power at operation time (tn) in the corresponding zone [W] (Refer to Fig. 3.3 and Chapter 3 Braking Capability Data in Technical Note 22.)

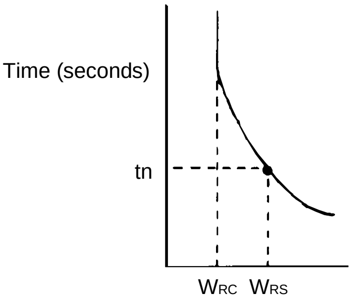


Fig. 3.3

Note

Types of regenerative braking systems

*When the inverter capacity is small and regenerative energy is small, power is temporarily charged in the smoothing capacitor. This system is called <u>capacitor-regenerative system</u> and used for upto 0.4kW or less.

*When a medium capacity inverter is used, the current flows to a resistor where it is converted to heat. This system is called <u>resistor-regenerative system</u>. When regenerative energy increases, the resistor size increases and the influence of heat generation on the surroundings must be noted.

*When the inverter capacity is large and regenerative energy is large, regenerative power is returned to the power supply. This system is called <u>power supply-regenerative system</u>.
It is recommended to adopt this system when <u>the continuous regenerative period is long, or a motor larger than a 15kW motor is used for a lifting operation.</u>

3.7 Thermal Examination of the Motor

(1) Operation pattern

When the frequency of starts is particularly high or long operation is performed at low speed for a lifter, find the current in each operation zone during cycle time and make sure that the average (RMS) current found by root-mean-squaring all currents is within the rated current value of the motor.

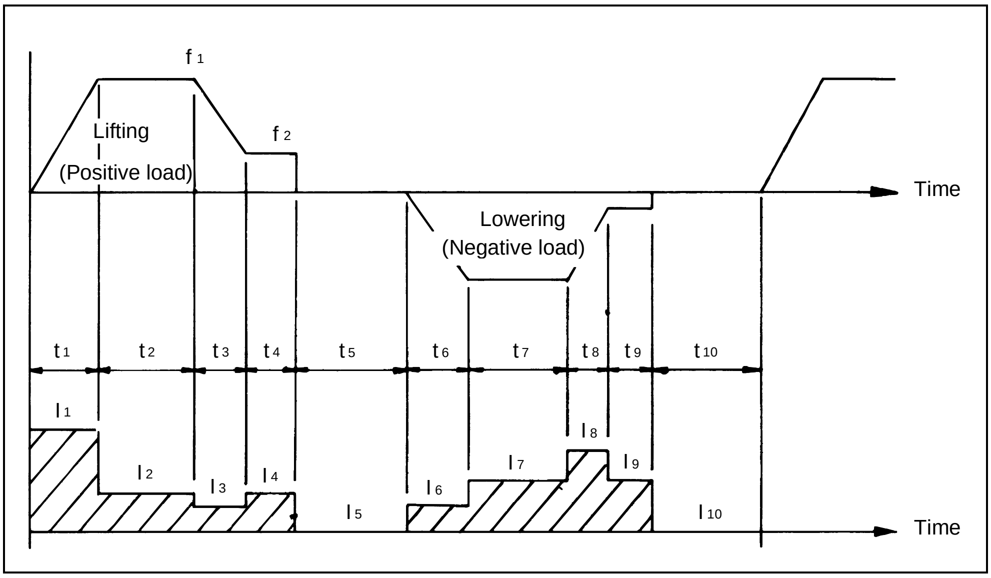


Fig. 3.4 Example of Operation Pattern

If the following formula is satisfied in Fig. 3.4, the motor can be used thermally.

$$I_{MC} = \sqrt{\frac{I_1^2 t_1 + I_2^2 t_2 + K\,K + I_n^2 t_n}{C_1 t_1 + C_2 t_2 + K\,K + C_n t_n}} < 100\ [\%]$$

I_{MC} : Motor equivalent current value in consideration of the cooling coefficient [%]
$I_1, I_2, \ldots I_n$: Current characteristics in operation zones $t_1, t_2, \ldots t_n$ [%]
$C_1, C_2, \ldots C_n$: Cooling coefficients for frequencies in operation zones $t_1, t_2, \ldots t_n$
Note: Make judgment at 50% when the cyclic operation mode of the vector inverter (FR-V200E) has been selected.

(2) How to find motor currents $I_1, I_2, \ldots I_n$ (%)

(a) Find the load torque factor in each operation zone.

	Zone Time [s]	Torque Supplied to the Load [kgf•m]	Load Torque [%]	Current Characteristic [%]	Cooling Co-efficient
During lifting	t_1 t_2, t_4 t_3	$T_{aup} = T_{a1} + T_{Uup} + Tfr_{up}$ $T_{LU} = T_{Uup} + Tfr_{up}$ $T_{dup} = -T_{d1} + T_{Uup} + Tfr_{up}$	TF = TF = TF =	I_1 I_2, I_4 I_3	C_1 C_2, C_4 C_3
During lowering	t_6 t_7, t_9 t_8	$T_{adn} = T_{a2} + T_{Udn} + Tfr_{dn}$ $T_{LD} = T_{Udn} + Tfr_{dn}$ $T_{ddn} = -T_{d2} + T_{Udn} + Tfr_{dn}$	TF = TF = TF =	I_6 I_7, I_9 I_8	C_6 C_7, C_9 C_8
During stop	t_5, t_{10}	$T = 0$	TF = 0	$I_5 = I_{10} = 0$	C_5, C_{10}

(b) Find the load torque factor.

$$\boxed{\text{Load torque factor (TF)} = \frac{\text{torque supplied to the load}}{\text{rated torque of the motor } (T_M)} \times 100\ [\%]}$$

In the constant-output region (region above the base frequency, e.g. 60 to 120Hz) of the motor, the load torque factor (TF) is as follows:

Load torque factor above the base frequency

$$\text{TF} = \frac{\text{torque supplied to the load}}{\text{rated torque of the motor } (T_M)} \times \frac{\text{running frequency}}{\text{base frequency}} \times 100\ [\%]$$

(c) How to find the motor current
Refer to (Motor and Brake Characteristics) in Technical Note No. 22 and find the motor current [%] corresponding to the load torque factor found in (b).
If the maximum frequency is higher than the base frequency of the inverter during acceleration/deceleration, multiply the found motor current value [%] by the current compensation coefficient ((Motor and Brake Characteristics) in Technical Note No. 22).

(3) How to find the cooling coefficients C_1, C_2, .. Cn
Refer to (Motor and Brake Characteristics) in Technical Note No. 22.

Note

If the average current is nearly 100%:

When a general-purpose motor is driven by the inverter, the motor current increases (about 1.1 times) to provide the same torque as when it is driven with the commercial power supply.
When the equivalent current value of the motor reaches 100%, that of the inverter-driven motor is about 110% therefore a general-purpose motor does not have thermal allowance. Hence, it is necessary to fully examine the load conditions and operation duty.

3.8 Stopping Accuracy

As all lifts have a mechanical brake for holding, stopping accuracy depends on the characteristics of the mechanical brake. Also, stopping accuracy can be improved by reducing the minimum velocity (f_{min}) of the inverter. However, f_{min} must be 6Hz or higher. Hence, the frequency at the minimum velocity (f_{min}) should be found from the characteristics of the mechanical brake and the required stopping accuracy as described below, and if f_{min} is less than 6Hz, the operating frequency range of the inverter must be reviewed.

(1) How to find the stopping distance

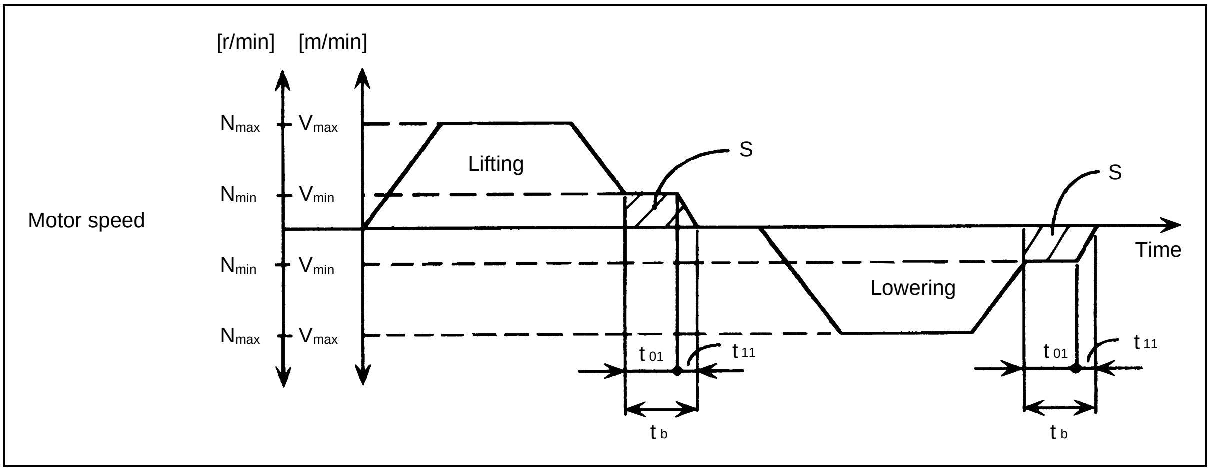


Fig. 3.5 Example of Speed Pattern

Generally, distance S between a stop command and a stop is found by the following formula:

$$S = \left(\frac{V_{min}}{60} \times t_{01} + \frac{1}{2} \times \frac{V_{min}}{60} \times t_{11}\right) \times 10^3$$

$$t_{11} = \frac{\Sigma GD^2 \times N_{min}}{38.2 \times (T_B + T_L)}$$

(The sign of TL is positive for driving and negative for regeneration.)

S	: Stopping distance	[mm]
V_{min}	: Velocity at low-speed frequency (f_{min})	[m/min]
N_{min}	: Motor speed at low-speed frequency (f_{min})	[r/min]
T_B	: Braking torque of the mechanical brake	[N•m]
t_{01}	: Operation delay time of the mechanical brake (including the delay time of the relay)	[s]

(2) Stopping accuracy

Stopping accuracy is the variation range of the above stopping distance (S) and is especially affected by V_{min}, t_{01} and T_B. To decrease the stopping distance (S), it is effective to reduce the minimum velocity (V_{min}).

Stopping accuracy is generally found by the following formula in consideration of the variation ranges of the above factors:

$$\text{Stopping accuracy } \Delta\varepsilon = \pm\frac{S}{2} \text{ [mm]}$$

CHAPTER 4 SPECIFIC SELECTION EXAMPLES

4.1 Selection Example 1) <With counterweight> [SI Systems of Units]

1. Machine Conditions Required for Examination

(1) Voltage and frequency of the power supply 200 [V] 50 [Hz]

(2) Required power P_L (When unknown, refer 2.2.) 5.45 [kW]

(3) Operating speed range of the motor N_{min} 180 to N_{max} 1800 [r/min]

(4) Number of motor poles 4 P

(5) Operating frequency range f_{min} 6 to f_{max} 60 [Hz]

(6) Weight of the drive section W

(a) Lift case's own weight W_T 2200 [kgf]

(b) Lifter load during lifting W_{Lup} 3000 [kgf]

(c) Lifter load during lowering W_{Ldn} 2200 [kgf]

(d) Counterweight W_C 4500 [kgf]

(e) Chain weight W_{CH} 350 [kgf]

(f) Chain eccentric load W_{CS} 300 [kgf]

(g) Pulley average diameter D_S 0.48 [m]

(h) Pulley-rope friction coefficient μ 0.085

(7) Lifting velocity V_{min} 3 to V_{max} 30 [m/min]

(8) Machine efficiency of the drive section η 0.9

(9) Load torque converted into the equivalent value at the motor shaft

(a) Load torque during lifting T_{LU} (When unknown, refer 2.1.) 53.6 [N•m]

(b) Load torque during lowering T_{LD} (When unknown, refer 2.1.) –26.1 [N•m]

Hence, make the following calculation on the assumption that maximum torque

T_{Lmax} = 53.6 [N•m].

(10) Load GD^2 converted into the equivalent value at the motor shaft

(a) GD^2 of the lift table GD^2_{WT} (When unknown, refer 2.1.) 0.0620 [kgf•m²]

(b) Lifter load during lifting GD^2_{WLUP} (When unknown, refer 2.1.) 0.0845 [kgf•m²]

(c) Lifter load during lowering GD^2_{WLdn} (When unknown, refer 2.1.) 0.0845 [kgf•m²]

(d) GD^2 of the counterweight GD^2_{WC} (When unknown, refer 2.1.) 0.1268 [kgf•m²]

(e) GD^2_{WLdn} of chain weight GD^2_{WLdn} (When unknown, refer 2.1.) 0.0099 [kgf•m²]

(f) GD^2 of the mechanical brake GD^2_B, etc. 0.15 [kgf•m²]

Total load converted into the equivalent value at the motor shaft during lifting GD^2_{Lup}

$= \{GD^2_{WT} + GD^2_{WLup} + GD^2_{WC} + GD^2_{WCH}\}$

= 0.0620 + 0.0845 + 0.1268 + 0.0099

= 0.2832 [kgf•m²]

Total load converted into the equivalent value at the motor shaft during lowering GD^2_{Ldn}

$= \{GD^2_{WT} + GD^2_{WLdn} + GD^2_{WC} + GD^2_{WCH}\}$

= 0.0620 + 0.0845 + 0.1268 + 0.0099

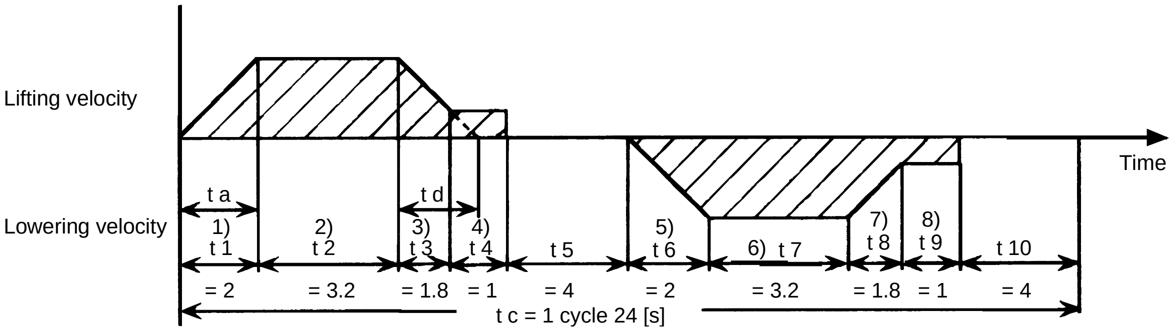
= 0.2832 [kgf•m²]

(11) Operation pattern

(a) Acceleration time ta *2.0* [s]

(b) Deceleration time td *2.0* [s]

(c) Time of one cycle tc *24.0* [s]



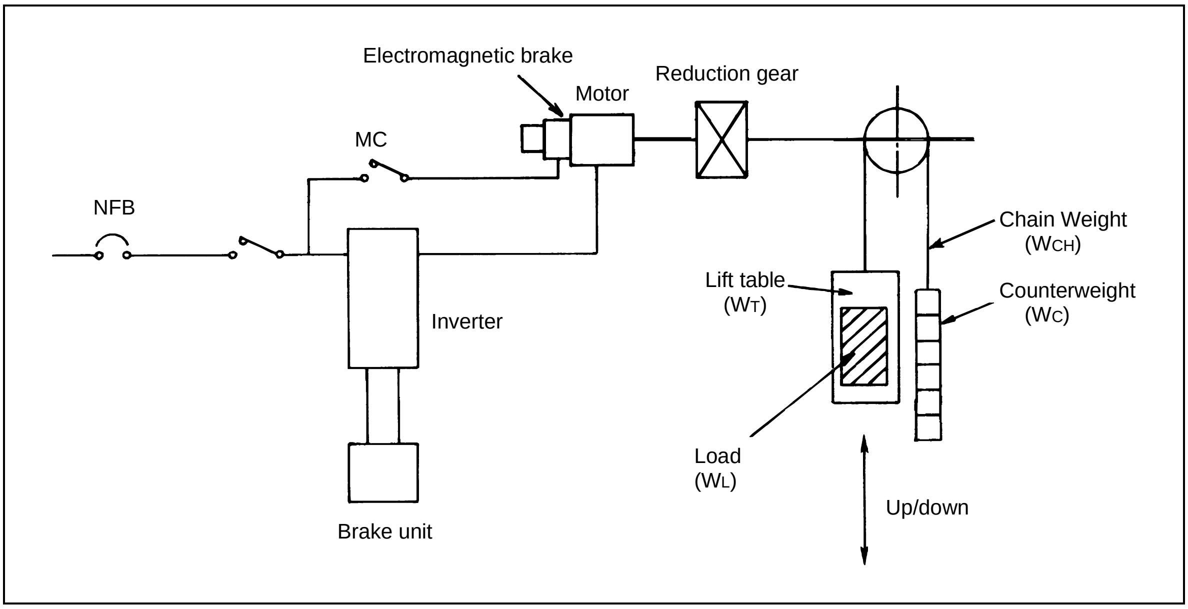


Fig. 4.1 General Structure of the Lift

2.1 Calculation of Load

(1) Pulley speed (N_2)

$N_2 = V/(\pi \times D_S) = \boxed{30/(\pi \times 0.48)} = \boxed{19.9}$ [r/min]

(2) Reduction ratio of the reduction gear (n)

Supposing that the motor is $\boxed{4}$ P and is run at $\boxed{60}$ Hz, $N_1 = \boxed{1800}$ [r/min]

$n = N_1/N_2 = \boxed{1800/19.9} = \boxed{90.5}$

(3) Moving distance of the lift per motor revolution (ΔS)

$$\Delta S = \frac{\pi \times Ds}{n} \times 10^3 = \frac{\pi \times \boxed{0.48}}{\boxed{90.5}} \times 10^3 = \boxed{16.7} \quad \text{[mm]}$$

(4) Calculation of load GD^2

(a) GD^2_{WT} of the lift table

$GD^2_{WT} = W_{LB} \times (V/\pi N_1)^2$

$= \boxed{2200 \times (30 / (\pi \times 1800))^2} = \boxed{0.0620}$ [kgf•m^2]

(b) GD^2_{WLup} of lifter load during lifting

$GD^2_{WLup} = W_{Lup} \times (V/\pi N_1)^2$

$= \boxed{3000 \times (30 / (\pi \times 1800))^2} = \boxed{0.0845}$ [kgf•m^2]

(c) GD^2_{WLdn} of lifter load during lowering

$GD^2_{WLdn} = W_{Ldn} \times (V/\pi N_1)^2$

$= \boxed{0 \times (30 / (\pi \times 1800))^2} = \boxed{0}$ [kgf•m^2]

(d) GD^2_{WC} of the counterweight

$GD^2_{WC} = W_C \times (V/\pi N_1)^2$

$= \boxed{4500 \times (30 / (\pi \times 1800))^2} = \boxed{0.1268}$ [kgf•m^2]

(e) GD^2_{CH} of chain

$GD^2_{CH} = W_{CH} \times (V/\pi N_1)^2$

$= \boxed{350 \times (30 / (\pi \times 1800))^2} = \boxed{0.0099}$ [kgf•m^2]

Total load converted into the equivalent value at the motor shaft during lifting

$GD^2_{Lup} = GD^2_{WT} + GD^2_{WLup} + GD^2_{WC} + GD^2_{WCH}$

$= \boxed{0.0620} + \boxed{0.0845} + \boxed{0.1268} + \boxed{0.0099}$

$= \boxed{0.2832}$ [kgf•m^2]

Total load converted into the equivalent value at the motor shaft during lowering

$GD^2_{Ldn} = GD^2_{WT} + GD^2_{WLdn} + GD^2_{WC} + GD^2_{WCH}$

$= \boxed{0.0620} + \boxed{0.0845} + \boxed{0.1268} + \boxed{0.0099}$

$= \boxed{0.2832}$ [kgf•m^2]

(5) Calculation of load torque converted into the equivalent value at the motor shaft (T_L)

(a) During lifting

$(W_T + W_{Lup}) \geq W_C$: $W_{up} = (W_T + W_{Lup} + W_{CS}) - W_C$

$$= \boxed{(2200 + 3000 + 300) - 4500} = \boxed{1000} \text{ [kgf]}$$

$(W_T + W_{Lup}) < W_C$: $W_{up} = (W_T + W_{Lup}) - (W_C + W_{CS})$

$$= \boxed{\text{————————}} = \boxed{\text{————}} \text{ [kgf]}$$

- When $W_{up} \geq 0$

  $T_{LU} = T_{Uup} + Tfr_{up}$

$$= \frac{W_{up} \times g \times \Delta S \times 10^{-3}}{2 \times \pi \times \eta} + \frac{\mu \times Wa_{up} \times g \times \Delta S \times 10^{-3}}{2 \times \pi \times \eta}$$

$$= \boxed{\frac{1000 \times 9.8 \times 16.7 \times 10^{-3}}{2 \times \pi \times 0.9}} + \boxed{\frac{0.085 \times 10000 \times 9.8 \times 16.7 \times 10^{-3}}{2 \times \pi \times 0.9}}$$

$$= \boxed{29.0} + \boxed{24.6} = \boxed{53.6} \text{ [N•m]}$$

- When $W_{up} < 0$ (To take safety into consideration, make calculation by setting the machine efficiency (η) to 1 and the friction coefficient (μ) to 0.)

  $T_{LU} = T_{Uup} \times \eta^2 + Tfr_{up}$

$$= \boxed{\frac{W_{up} \times 9.8 \times \Delta S \times 10^{-3}}{2 \times \pi \times}} \times 1^2 + \boxed{\frac{0 \times Wa_{up} \times 9.8 \times \Delta S \times 10^{-3}}{2 \times \pi \times}}$$

$$= \boxed{\frac{\text{————————}}{\text{————————}}} \times 1^2 + 0 = \boxed{\text{————}} \text{ [N•m]}$$

where,

T_{Uup} : Unbalance torque during lifting [N•m]

Tfr_{up} : Friction torque of drive section during lifting [N•m]

Wa_{up} : Total weight during lifting ($W_T + W_{Lup} + W_{CS} + W_C$) [kgf]

(b) During lowering

$(W_T + W_{Ldn}) \ge W_C$: $W_{dn} = W_C - (W_T + W_{Ldn} + W_{CS})$

$$= \boxed{4500 - (2200 + 3000 + 300)} = \boxed{-1000} \text{ [kgf]}$$

$(W_T + W_{Ldn}) < W_C$: $W_{dn} = (W_C + W_{CS}) - (W_T + W_{Ldn})$

$$= \boxed{\text{————————————}} = \boxed{\text{————}} \text{ [kgf]}$$

- When $W_{dn} \ge 0$

  $T_{LD} = T_{Udn} + Tfr_{dn}$

  $$= \frac{W_{dn} \times g \times \Delta S \times 10^{-3}}{2 \times \pi \times \eta} + \frac{\mu \times Wa_{dn} \times g \times \Delta S \times 10^{-3}}{2 \times \pi \times \eta}$$

  $$= \boxed{\frac{\text{——————}}{\text{——————}}} + \boxed{\frac{\text{——————}}{\text{——————}}}$$

  $$= \boxed{\text{————}} + \boxed{\text{————}} = \boxed{\text{————}} \text{ [N•m]}$$

- When $W_{dn} < 0$ (To take safety into consideration, make calculation by setting the machine efficiency (η) to 1 and the friction coefficient (μ) to 0.)

  $T_{LD} = T_{Udn} \times \eta^2 + Tfr_{dn}$

  $$= \boxed{\frac{W_{dn} \times g \times \Delta S \times 10^{-3}}{2 \times \pi \times 1.0}} \times 1^2 + \boxed{\frac{0 \times Wa_{dn} \times g \times \Delta S \times 10^{-3}}{2 \times \pi \times 1.0}}$$

  $$= \boxed{\frac{-1000 \times 9.8 \times 16.7 \times 10^{-3}}{2 \times \pi \times 1.0}} \times 1^2 + 0 = \boxed{-26.1} \text{ [N•m]}$$

  where, T_{Udn} : Unbalance torque during lowering [N•m]
  Tfr_{dn} : Friction torque of drive section during lowering [N•m]
  Wa_{dn} : Total weight during lowering ($W_T + W_{Ldn} + W_{CS} + W_C$) [kgf]

  Hence, make the following calculation with the max. load torque $T_{Lmax} = \boxed{53.6}$ [N•m].

2.2 Selection of motor capacity

(1) Required power of the load

$$P_L = \frac{W \times V}{6120 \times h} \quad (\text{W is larger of } |W_{up}| \text{ and } |W_{dn}|)$$

$$= \boxed{\frac{1000 \times 30}{6120 \times 0.9}} = \boxed{5.45} \text{ [kW]}$$

(2) Temporary selection of motor capacity (P_M)

$$P_M = \alpha p \times P_L \quad (\alpha p = 0.5 \text{ to } 2.0)$$

$$= \boxed{1.0} \times \boxed{5.45} = \boxed{5.45} \text{ [kW]} \Rightarrow \text{Select } \boxed{11} \text{ [kW].}$$

(3) GD^2 of the motor, etc.

Motor $GD^2_M = \boxed{0.28}$ [kgf•m^2] (For the 11kW 4P motor)

(4) GD^2_B of the mechanical brake

Motor $GD^2_B = \boxed{0.15}$ [kgf•m^2] Note that the brake is the NB-$\boxed{15C}$.

Total GD^2_{up} converted into the equivalent value at the motor shaft during lifting

$$GD^2_{up} = GD^2_M + GD^2_B + GD^2_{Lup} = \boxed{0.28} + \boxed{0.15} + \boxed{0.2832}$$

$$= \boxed{0.7132} \text{ [kgf•m}^2\text{]}$$

Total GD^2_{dn} converted into the equivalent value at the motor shaft during lowering

$$GD^2_{dn} = GD^2_M + GD^2_B + GD^2_{Ldn} = \boxed{0.28} + \boxed{0.15} + \boxed{0.2832}$$

$$= \boxed{0.7132} \text{ [kgf•m}^2\text{]}$$

2.3 Temporary selection of inverter capacity

(1) Rated torque (T_M) of the temporarily selected motor (60Hz rating basis)

$$T_M = \frac{9550 \times P_M}{N_M} = \boxed{\frac{9550 \times 11}{1800}} = \boxed{58.36} \text{ [N•m]}$$

(2) Temporary selection of the inverter capacity

According to the motor capacity, select the $\boxed{\text{FR-A520-11K}}$.

(3) Determination of the torque type

According to the motor and inverter temporarily selected, the torque type is $\boxed{15A1}$ with reference to Technical Note No. 22. (Advanced magnetic flux vector control)

Maximum starting torque coefficient $\alpha_s = \boxed{1.5}$

Linear acceleration torque coefficient $\alpha_a = \boxed{1.4}$

Hot coefficient $\sigma = \boxed{0.94}$

(4) Operating frequency range of the temporarily selected inverter

According to $f = \dfrac{\text{motor speed} \times \text{number of motor poles}}{120}$

Frequency corresponding to the maximum speed

$$f_{max} = \frac{N_{max} \times P}{120} = \boxed{\frac{1800 \times 4}{120}} = \boxed{60} \text{ [Hz]}$$

Frequency corresponding to the minimum speed

$$f_{min} = \frac{N_{min} \times P}{120} = \boxed{\frac{180 \times 4}{120}} = \boxed{6} \text{ [Hz]}$$

2.4 Whether the Motor Can Be Started and Run at Low Speed or Not

(1) Motor starting torque (T_{MS}) $= T_M \times \alpha_s \times \sigma = \boxed{58.36 \times 1.5 \times 0.94} = \boxed{82.3}$ [N•m]

(For α_s and σ, refer to Technical Note No. 22.)

(2) Supposing that load torque at start (T_{LS}) = maximum load torque (T_{Lmax})

Judgment of whether the motor can be started or not

$T_{LS} = \boxed{53.6} < T_{MS} = \boxed{82.3}$ OK

(3) Short-time maximum torque at f_{min} (6Hz or more)

$T_{M1} = T_M \times \alpha_m \times \sigma = \boxed{58.36 \times 1.5 \times 0.94} = \boxed{82.3}$ [N•m]

(For α_m and σ, refer to Technical Note No. 22.)

Judgment of whether low-speed operation can be performed or not

$T_{LS} = \boxed{53.6} < T_{M1} = \boxed{82.3}$ OK

$T_{LS} = \boxed{53.6} < T_{MS} = \boxed{82.3}$

2.5 Whether Acceleration/Deceleration is Possible or Not

(1) Acceleration torque during lifting (Ta_1)

$$= \frac{(GD^2_{Lup} + GD^2_M + GD^2_B) \times N_{max}}{38.2 \times t_a} = \boxed{\frac{0.7132 \times 1800}{38.2 \times 2.0}} = \boxed{16.8} \text{ [N•m]}$$

(2) Deceleration torque during lifting (Td_1)

$$= \frac{(GD^2_{Lup} + GD^2_M + GD^2_B) \times N_{max}}{38.2 \times t_d} = \boxed{\frac{0.7132 \times 1800}{38.2 \times 2.0}} = \boxed{16.8} \text{ [N•m]}$$

(3) Acceleration torque during lowering (Ta_2)

$$= \frac{(GD^2_{Ldn} + GD^2_M + GD^2_B) \times N_{max}}{38.2 \times t_a} = \boxed{\frac{0.7132 \times 1800}{38.2 \times 2.0}} = \boxed{16.8} \text{ [N•m]}$$

(4) Deceleration torque during lowering (Td_2)

$$= \frac{(GD^2_{Ldn} + GD^2_M + GD^2_B) \times N_{max}}{38.2 \times t_d} = \boxed{\frac{0.7132 \times 1800}{38.2 \times 2.0}} = \boxed{16.8} \text{ [N•m]}$$

(5) Torque applied to the motor in each region

	Region	Torque applied to the motor [N•m]
Lifting	1)	$Ta_{up} = T_{a1} + T_{LU} = \boxed{16.8 + 53.6} = \boxed{70.4}$
	2)	$T_{LU} = \boxed{53.6}$
	3)	$Td_{up} = -T_{d1} + T_{LU} = \boxed{-16.8 + 53.6} = \boxed{36.8}$
	4)	$T_{LU} = \boxed{53.6}$
Lowering	5)	$Ta_{dn} = T_{a2} + T_{LD} = \boxed{16.8 - 26.1} = \boxed{-9.3}$
	6)	$T_{LD} = \boxed{-26.1}$
	7)	$Td_{dn} = -T_{d2} + T_{LD} = \boxed{-16.8 - 26.1} = \boxed{-42.9}$
	8)	$T_{LD} = \boxed{-26.1}$

(6) Torque required for acceleration and deceleration

(a) Torque coefficient required for acceleration during rising (α)

$$= \frac{Ta_{max}}{T_M} = \boxed{\frac{70.4}{58.36}} = \boxed{1.21}$$

Ta_{max} is either of Ta_{up} in region 1 and Ta_{dn} in region 5, which is larger.
Note that regenerative acceleration is made when $Ta_{up} < 0$ and $Ta_{dn} < 0$. In this case, the maximum torque required for regeneration is judged by whether deceleration is possible or not. Hence, the judgment of whether acceleration is possible or not is not needed here.

Analysis of whether acceleration is possible or not

$\alpha_a \times \sigma = \boxed{1.4} \times \boxed{0.94} > \alpha = \boxed{1.21}$ OK

α_a: Linear acceleration torque coefficient
δ: Heat coefficient (refer to Technical Note No. 22.)

(b) Torque coefficient required for deceleration during lowering (β)

$$= \frac{|Td_{max}|}{T_M} = \boxed{\frac{42.9}{58.36}} = \boxed{0.74}$$

Td_{max} is either of Td_{up} in region 3 and Td_{dn} in region 7, which is smaller.
Note that driving deceleration is made when $Td_{up} > 0$ and $Td_{dn} > 0$. In this case, the maximum torque required for driving is judged by whether acceleration is possible or not. Hence, the judgment of whether deceleration is possible or not is not needed here.

(c) Temporary selection of the brake unit

The torque type of the *FR-BU-15K* is *10B* .
<Refer to the braking capability data in Technical Note No. 22.>

Analysis of whether deceleration is possible or not

$\beta_{min} = \boxed{1.0} > \beta = \boxed{0.74}$ OK

β_{min}: Brake torque coefficient (minimum value)

2.6 Examination of Thermal Capacity of the Brake Unit

(1) Operation pattern

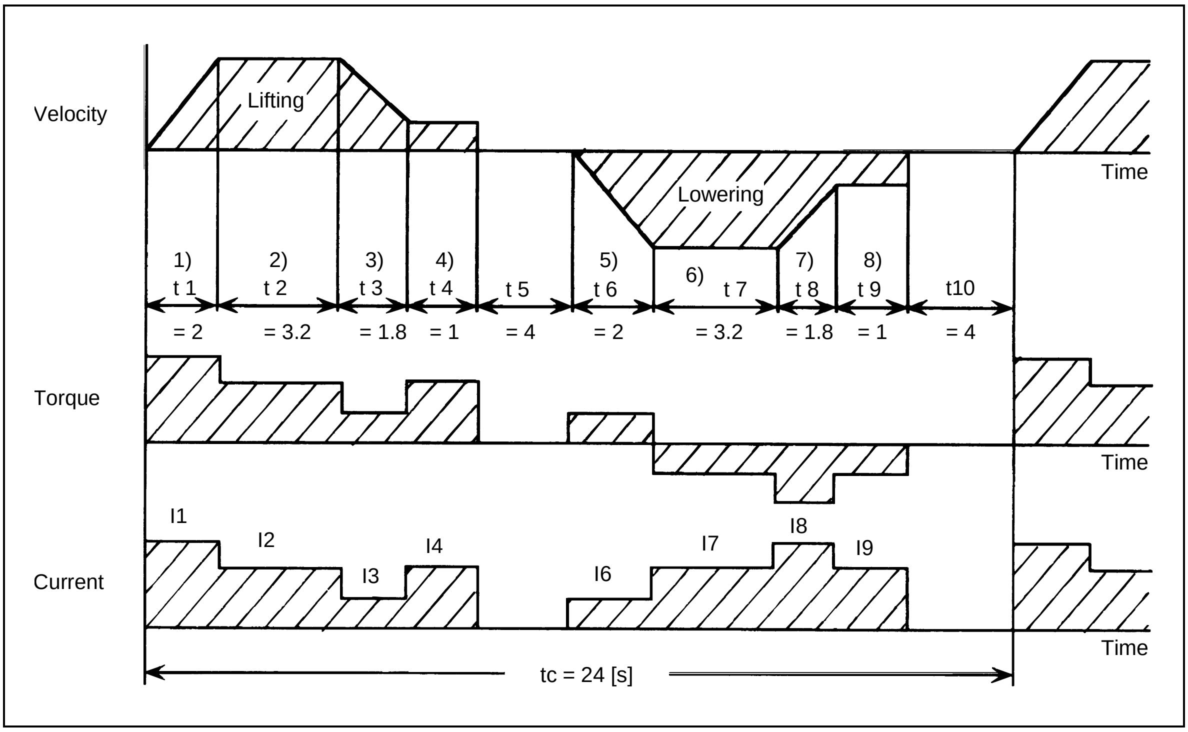


Fig. 4.2 Example of Operation Pattern

(2) Formulas for calculating the regenerative power in each operation zone

Zone	Regenerative Power [W]
1)	$W_1 = 0.1047 \times \frac{N_1}{2} \times T_{aup} = \boxed{0.1047 \times (1800 / 2) \times 70.4} = \boxed{6634}$
2)	$W_2 = 0.1047 \times N_1 \times T_{LU} = \boxed{0.1047 \times 1800 \times 53.6} = \boxed{10101}$
3)	$W_3 = 0.1047 \times \frac{N_1 + N_2}{2} \times T_{dup} = \boxed{0.1047 \times (1800 + 180) / 2 \times 36.8} = \boxed{3814}$
4)	$W_4 = 0.1047 \times N_2 \times T_{LU} = \boxed{0.1047 \times 180 \times 53.6} = \boxed{1010}$
5)	$W_6 = 0.1047 \times \frac{N_1}{2} \times T_{adn} = \boxed{0.1047 \times (1800 / 2) \times (-9.3)} = \boxed{-876}$
6)	$W_7 = 0.1047 \times N_1 \times T_{LD} = \boxed{0.1047 \times 1800 \times (-26.1)} = \boxed{4919}$
7)	$W_8 = 0.1047 \times \frac{N_1 + N_2}{2} \times T_{ddn} = \boxed{0.1047 \times (1800 + 180) / 2 \times (-42.9)} = \boxed{-4447}$
8)	$W_9 = 0.1047 \times N_2 \times T_{LD} = \boxed{0.1047 \times 180 \times (-26.1)} = \boxed{-492}$

(3) Calculation of power

- Power returned from the load [W_{MECH}]

$$W_{MECH} = \frac{|\Sigma(W_n \times t_n)|}{\Sigma t_n}$$

From zones in 1) to 8), calculate W_n and t_n only in zone 5), 6), 7), 8) where power is negative.

$$= \boxed{\frac{|(-876)\times 2+(-4919)\times 3.2+(-4447)\times 1.8+(-492)\times 1|}{8}} = \boxed{3249} \text{ [W]}$$

- Power returned to the inverter

$W_{INV} = W_{MECH} \times 0.9 = \boxed{3249 \times 0.9} = \boxed{2924}$ [W]

(4) Short-time permissible power per operation of the braking unit $W_{RS} = \boxed{5400}$ [W]
BU-15K (For W_{RS}, refer to Technical Note No. 22.)

Judgment of short-time permissible power

$W_{INV} = \boxed{2924} < W_{RS} = \boxed{5400}$ OK

(5) Checking the continuous average regenerative power

$$W_{INV} \times \frac{t_1 + t_2 + \ldots + t_n}{t_c} = \boxed{2924 \times \frac{8}{24}} = \boxed{97.5} \text{ [W]}$$

(t_1 to t_n is the sum total of times when power is negative in operation zones 1) to 8))

(6) Continuous permissible power W_{RC} (refer to Technical Note No. 22) = $\boxed{1200}$ [W]

Judgment of continuous permissible power

$W_{INV} \times \frac{t}{t_c} = \boxed{97.5} < W_{RC} = \boxed{1200}$ OK

(7) Checking the short-time permissible power in the continuous regenerative operation zone

$W_n \times 0.9 = \boxed{2924} < W_{RS}$ (for 8 seconds) = $\boxed{5400}$ OK
(For W_{RS} for 8 seconds, refer to Technical Note No. 22.)

2.7 Examination of Whether the Motor Can Be Used Thermally

(1) Required motor torque, load torque factor and current characteristic (%)

	Zone	Torque Supplied to the Load	Load Torque Factor [%]	Current Characteristic [%]	Cooling Coefficient
During rising	t_1	$T_{aup} = T_{a1} + T_{LU}$			
		= 70.4	TF = 120.6	I1 = 119	C1 = 0.76
	t_2	T_{LU} = 53.6		I2 = 93	C2 = 1.0
	t_4		TF = 91.8	I4 = 93	C4 = 0.4
	t_3	$T_{dup} = -T_{d1} + T_{LU}$			
		= 36.8	TF = 63.1	I3 = 73	C3 = 0.80
During falling	t_6	$T_{adn} = T_{a2} + T_{LD}$			
		= –9.3	TF = 15.9	I6 = 44	C6 = 0.76
	t_7	T_{LD} = –26.1		I7 = 59	C7 = 1.0
	t_9		TF = 44.7	I9 = 59	C9 = 0.4
	t_8	$T_{ddn} = -T_{d2} + T_{LD}$			
		= –42.9	TF = 73.5	I8 = 79	C8 = 0.80

Note: Motor torque used is the above calculated value.

(2) Motor equivalent current value (I_{MC})

$$I_{MC} = \sqrt{\frac{I_1^2 \times t_1 + I_2^2 \times t_2 \ldots\ldots + I_n^2 \times t_n}{C_1 \times t_1 + C_2 \times t_2 + \ldots + C_n \times t_n}}$$

$$= \sqrt{\frac{(119^2 \times 2 + 93^2 \times 3.2 + 73^2 \times 1.8 + 93^2 \times 1) + (44^2 \times 2 + 59^2 \times 3.2 + 79^2 \times 1.8 + 59^2 \times 1)}{(0.76 \times 2 + 1.0 \times 3.2 + 0.8 \times 1.8 + 0.4 \times 1 + 0.4 \times 4) + (0.76 \times 2 + 1.0 \times 3.2 + 0.8 \times 1.8 + 0.4 \times 1 + 0.4 \times 4)}}$$

$$= \sqrt{\frac{74240 + 29726}{8.16 + 8.16}} = \frac{322.4}{4.04} = \boxed{79.8} < 100\% \qquad \boxed{\text{OK}}$$

2.8 Examination of Stopping Accuracy

(1) Characteristics of the brake

According to Technical Note No. 22, the characteristics of the mechanical brake $\boxed{\textit{NB-15C}}$ are:

- Rated braking torque : $T_B = \boxed{147}$ [N•m]
- Delay time (independent off) : $t_{01} = \boxed{0.025}$ [s]
- Brake GD^2 : $GD^2_B = \boxed{0.15}$ [kgf•m^2]

(2) Stopping accuracy when the motor running at a slow speed (creep speed), and is brought to a stop

Stopping time (t_b)

$$= t_{01} + t_{11}$$

$$= t_{01} + \frac{(GD_L^2 + GD_M^2 + GD_B^2) \times N_{min}}{38.2 \times (T_B + T_L)}$$

$$= \boxed{0.025} + \boxed{\frac{0.7132 \times 180}{38.2 \times (147 - 26.1)}}$$

$$= \boxed{0.025 \ + \ 0.028}$$

$$= \boxed{0.053} \text{ [s]}$$

(Stopping time during lowering)

where,

T_L : Load torque during lifting (T_{LU})

: Load torque during lowering (T_{LD})

Stopping distance (S)

$$= S_{01} + S_{11} = (t_{01} \times \frac{V_{min}}{60} + t_{11} \times \frac{V_{min}}{60} \times \frac{1}{2}) \times 10^3$$

$$= (\boxed{0.025 \times 3 / 60} + \boxed{0.028 \times 3 / 60 \times 1 / 2}) \times 10^3$$

$$= \boxed{1.950} \text{ [mm]}$$

Guideline of stopping accuracy ($\Delta\varepsilon$) = ±S/2 = $\boxed{1.950/2}$ = ± $\boxed{0.98}$ [mm]

2.9 Determination of the Models

According to the above examination results, the recommended models are as follows:

Motor	:	11kW 4P
Inverter	:	FR-A520-11K (Control system: Advanced magnetic flux vector control)
Braking unit	:	BU-15K

4.2 Selection Example 2) <Without counterweight>

[Gravitational Systems of Units]

1. Machine Conditions Required for Examination

(1) Voltage and frequency of the power supply *220* [V] *60* [Hz]

(2) Required power P_L (When unknown, refer 2.2.) *4.36* [kW]

(3) Operating speed range of the motor N_{min} *180* to N_{max} *1800* [rpm]

(4) Number of motor poles *4* P

(5) Operating frequency range f_{min} *6* to f_{max} *60* [Hz]

(6) Weight of the drive section W

- (a) Lift table own weight W_T *400* [kgf]
- (b) Lifter load during lifting W_{Lup} *250* [kgf]
- (c) Lifter load during lowering W_{Ldn} *0* [kgf]
- (d) Counterweight W_C ——— [kgf]
- (e) Chain weight W_{CH} *200* [kgf]
- (f) Chain eccentric load W_{CS} *150* [kgf]
- (g) Pulley average diameter D_S *1.0614* [m]
- (h) Pulley-rope friction coefficient μ *0.09*

(7) Lifting velocity V_{min} *3* to V_{max} *30* [m/min]

(8) Machine efficiency of the drive section η *0.9*

(9) Load torque converted into the equivalent value at the motor shaft

- (a) Load torque during lifting T_{LU} (When unknown, refer 2.1.) *2.573* [kgf•m]
- (b) Load torque during lowering T_{LD} (When unknown, refer 2.1.) *–1.699* [kgf•m]

Hence, make the following calculation on the assumption that maximum torque

T_{Lmax} = *2.573* [kgf•m].

(10) Load GD^2 converted into the equivalent value at the motor shaft

- (a) GD^2 of the lift table GD^2_{WT} (When unknown, refer 2.1.) *0.0113* [kgf•m^2]
- (b) Lifter load during lifting GD^2_{WLup} (When unknown, refer 2.1.) *0.0070* [kgf•m^2]
- (c) Lifter load during lowering GD^2_{WLdn} (When unknown, refer 2.1.) ——— [kgf•m^2]
- (d) GD^2 of the counterweight GD^2_{WC} (When unknown, refer 2.1.) ——— [kgf•m^2]
- (e) Chain weight GD^2_{WCH} (When unknown, refer 2.1.) *0.0056* [kgf•m^2]
- (f) GD^2 of the mechanical brake GD^2_B, etc. *0.062* [kgf•m^2]

Total load GD^2 converted into the equivalent value at the motor shaft GD^2_{Lup}

= {$GD^2_{WT} + GD^2_{WLup} + GD^2_{WC} + GD^2_{WCH}$ }

= *0.0113* + *0.0070* + ——— + *0.0056*

= *0.02248* [kgf•m^2]

Total load converted into the equivalent value at the motor shaft during lowering GD^2_{Ldn}

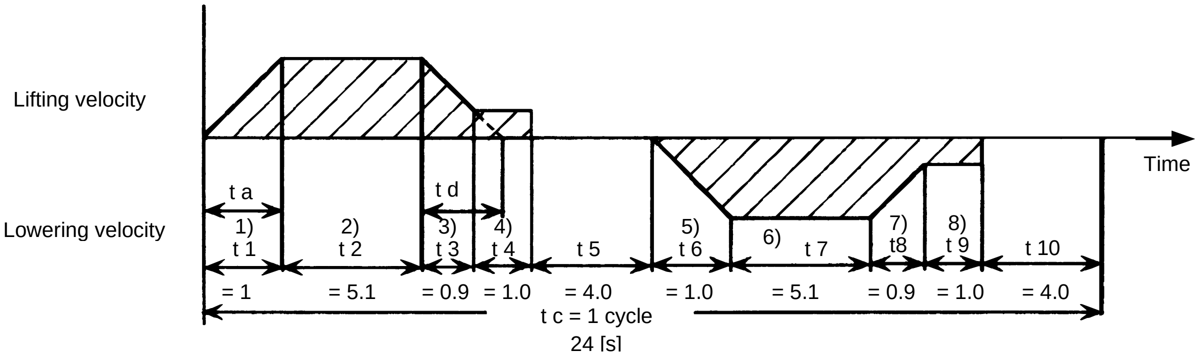
= {$GD^2_{WT} + GD^2_{WLdn} + GD^2_{WC} + GD^2_{WCH}$ }

= *0.0113* + *0* + ——— + *0.0056*

= *0.0169* [kgf•m^2]

(11) Operation pattern

(a)	Acceleration time	ta	*1.0*	[s]
(b)	Deceleration time	td	*1.0*	[s]
(c)	Time of one cycle	tc	*24.0*	[s]



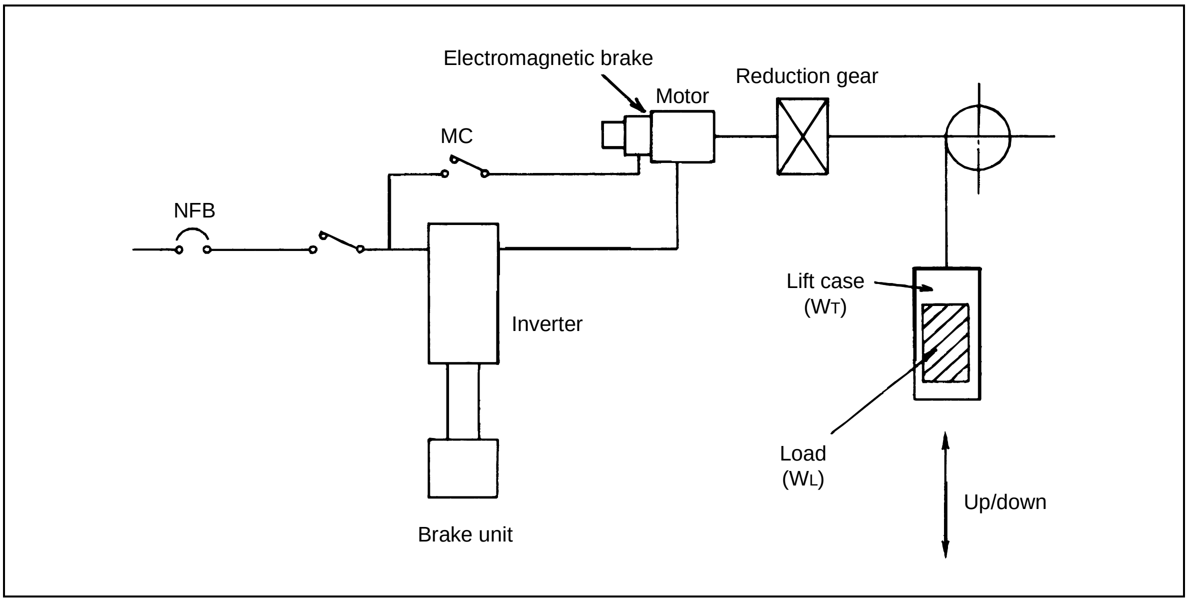


Fig. 4.3 General Structure of the Lift

2. Calculation of Load Specifications Required for Calculation

2.1 Determination of reduction ratio

(1) Pulley speed (N_2)

$N_2 = V/(\pi \times D_S) = \boxed{30 / (\pi \times 0.10614)} = \boxed{90}$ [rpm]

(2) Reduction ratio of the reduction gear (n)

Supposing that the motor is $\boxed{4}$ P and is run at $\boxed{60}$ Hz, $N_1 = \boxed{1800}$ [rpm]

$n = N_1/N_2 = \boxed{1800/90} = \boxed{20}$

(3) Moving distance of the lift per motor revolution (ΔS)

$$\Delta S = \frac{\pi \times Ds}{n} \times 10^3 = \frac{\pi \times \boxed{0.10614}}{\boxed{20}} \times 10^3 = \boxed{16.7} \quad \text{[mm]}$$

(4) Calculation of load GD^2

(a) GD^2_{WT} of the lift case

$GD^2_{WT} = W_{LB} \times (V/\pi N_1)^2$

$= \boxed{400 \times (30 / (\pi \times 1800))^2} = \boxed{0.0113}$ [kgf•m^2]

(b) GD^2_{WLup} of the lift load

$GD^2_{WLup} = W_{Lup} \times (V/\pi N_1)^2$

$= \boxed{250 \times (30 / (\pi \times 1800))^2} = \boxed{0.0070}$ [kgf•m^2]

(c) GD^2_{WLdn} of lifter load during lowering

$GD^2_{WLdn} = W_{Ldn} \times (V/\pi N_1)^2$

$= \boxed{0 \times (30 / (\pi \times 1800))^2} = \boxed{0}$ [kgf•m^2]

(d) GD^2_{WC} of the counterweight

$GD^2_{WC} = W_C \times (V/\pi N_1)^2$

$= \boxed{\text{————}} = \boxed{\text{———}}$ [kgf•m^2]

(e) GD^2_{CH} of chain

$GD^2_{CH} = W_{CH} \times (V/\pi N_1)^2$

$= \boxed{200 \times (30 / (\pi \times 1800))^2} = \boxed{0.0056}$ [kgf•m^2]

Total load converted into the equivalent value at the motor shaft during lifting

$GD^2_{Lup} = GD^2_{WT} + GD^2_{WLup} + GD^2_{WC} + GD^2_{WCH}$

$= \boxed{0.0113} + \boxed{0.0070} + \boxed{\text{———}} + \boxed{0.0056}$

$= \boxed{0.0239}$ [kgf•m^2]

Total load converted into the equivalent value at the motor shaft during lowering

$GD^2_{Ldn} = GD^2_{WT} + GD^2_{WLdn} + GD^2_{WC} + GD^2_{WCH}$

$= \boxed{0.0113} + \boxed{0} + \boxed{\text{———}} + \boxed{0.0056}$

$= \boxed{0.0169}$ [kgf•m^2]

(5) Calculation of load torque converted into the equivalent value at the motor shaft (T_L)

(a) During lifting

$(W_T + W_{Lup}) \geq W_C$: $W_{up} = (W_T + W_{Lup} + W_{CS}) - W_C$

$$= \boxed{\mathit{(400 + 250 + 150) - 0}} = \boxed{\mathit{800}} \text{ [kgf]}$$

$(W_T + W_{Lup}) < W_C$: $W_{up} = (W_T + W_{Lup}) - (W_C + W_{CS})$

$$= \boxed{\text{————————————}} = \boxed{\text{————}} \text{ [kgf]}$$

- When $W_{up} \geq 0$

$T_{LU} = T_{Uup} + Tfr_{up}$

$$= \frac{W_{up} \times \Delta S \times 10^{-3}}{2 \times \pi \times \eta} + \frac{\mu \times Wa_{up} \times \Delta S \times 10^{-3}}{2 \times \pi \times \eta}$$

$$= \boxed{\frac{800 \times 16.7 \times 10^{-3}}{2 \times \pi \times 0.9}} + \boxed{\frac{0.09 \times 800 \times 16.7 \times 10^{-3}}{2 \times \pi \times 0.9}}$$

$$= \boxed{\mathit{2.36}} + \boxed{\mathit{0.213}} = \boxed{\mathit{2.573}} \text{ [kgf•m]}$$

- When $W_{up} < 0$ (To take safety into consideration, make calculations by setting the machine efficiency (η) to 1 and the friction coefficient (μ) to 0.)

$T_{LU} = T_{Uup} \times \eta^2 + Tfr_{up}$

$$= \boxed{\frac{W_{up} \times \Delta S \times 10^{-3}}{2 \times \pi \times}} \times 1^2 + \boxed{\frac{0 \times Wa_{up} \times \Delta S \times 10^{-3}}{2 \times \pi \times}}$$

$$= \boxed{\frac{\text{——————}}{\text{——————}}} \times 1^2 + 0 = \boxed{\text{————}} \text{ [kgf•m]}$$

where, T_{Uup} : Unbalance torque during lifting [kgf•m]
Tfr_{up} : Friction torque of drive section during lifting [kgf•m]
Wa_{up} : Total weight during lifting [kgf]

(b) During lowering

$(W_T + W_{Ldn}) \geq W_C$: $W_{dn} = W_C - (W_T + W_{Ldn} + W_{CS})$

$= \boxed{0 - (400 + 150\ )} = \boxed{-550}$ [kgf]

$(W_T + W_{Ldn}) < W_C$: $W_{dn} = (W_C + W_{CS}) - (W_T + W_{Ldn})$

$= \boxed{\qquad\qquad\qquad} = \boxed{\qquad\qquad}$ [kgf]

- When $W_{dn} \geq 0$

$T_{LD} = T_{Udn} + Tfr_{dn}$

$$= \frac{W_{dn} \times \Delta S \times 10^{-3}}{2 \times \pi \times \eta} + \frac{\mu \times Wa_{dn} \times \Delta S \times 10^{-3}}{2 \times \pi \times \eta}$$

$$= \boxed{\frac{\qquad\qquad}{\qquad\qquad}} + \boxed{\frac{\qquad\qquad}{\qquad\qquad}}$$

$$= \boxed{\qquad\qquad} + \boxed{\qquad\qquad} = \boxed{\qquad\qquad} \text{ [kgf•m]}$$

- When $W_{dn} < 0$ (To take safety into consideration, make calculation by setting the machine efficiency (η) to 1 and the friction coefficient (μ) to 0.)

$T_{LD} = T_{Udn} \times \eta^2 + Tfr_{dn}$

$$= \boxed{\frac{W_{dn} \times \Delta S \times 10^{-3}}{2 \times \pi \times}} \times 1^2 + \boxed{\frac{0 \times Wa_{dn} \times \Delta S \times 10^{-3}}{2 \times \pi \times}}$$

$$= \boxed{\frac{-550 \times 16.7 \times 10^{-3}}{2 \times \pi \times 10}} \times 1^2 + 0 = \boxed{-1.463} \text{ [kgf•m]}$$

where,
T_{Udn} : Unbalance torque during lowering [kgf•m]
Tfr_{dn} : Friction torque of drive section during lowering [kgf•m]
Wa_{dn} : Total weight during lowering [kgf]

Hence, make the following calculation with the max. load torque (T_{Lmax}) = $\boxed{2.573}$ [N•m].

2.2 Selection of motor capacity

(1) Required power of the load

$$P_L = \frac{W \times V}{6120 \times \eta} \quad \text{(W is larger of } |W_{up}| \text{ and } |W_{dn}|\text{)}$$

$$= \boxed{\frac{800 \times 30}{6120 \times 0.9}} = \boxed{4.36} \text{ [kW]}$$

(2) Temporary selection of motor capacity (P_M)

$P_M = \alpha p \times P_L$ (αp= 0.5 to 2.0)

$$= \boxed{1.5} \times \boxed{4.36} = \boxed{6.54} \text{ [kW]} \Rightarrow \text{Select } \boxed{7.5} \text{ [kW].}$$

(3) GD^2 of the motor, etc.

Motor $GD^2_M = \boxed{0.16}$ [kgf•m^2] (For the 7.5kW 4P motor)

(4) GD^2_B of the mechanical brake

$GD^2_B = \boxed{0.062}$ [kgf•m^2] Note that the brake is the NB-$\boxed{7.5C}$.

Total GD^2_{up} converted into the equivalent value at the motor shaft during lifting is:

$$GD^2 = GD^2_M + GD^2_B + GD^2_{Lup} = \boxed{0.16} + \boxed{0.062} + \boxed{0.0239}$$

$$= \boxed{0.2459} \text{ [kgf•m}^2\text{]}$$

Total GD^2_{dn} converted into the equivalent value at the motor shaft during lowering is:

$$GD^2_{dn} = GD^2_M + GD^2_B + GD^2_{Ldn} = \boxed{0.16} + \boxed{0.062} + \boxed{0.0169}$$

$$= \boxed{0.2389} \text{ [kgf•m}^2\text{]}$$

2.3 Temporary selection of inverter capacity

(1) Rated torque (T_M) of the temporarily selected motor (60Hz rating basis)

$$T_M = \frac{974 \times P_M}{N_M} = \boxed{\frac{974 \times 7.5}{1800}} = \boxed{4.06} \text{ [kgf•m]}$$

(2) Temporary selection of the inverter capacity

According to the motor capacity, select the $\boxed{\text{FR-A520-7.5K}}$.

(3) Determination of the torque type

According to the motor and inverter temporarily selected, the torque type is $\boxed{15A0}$ with reference to Technical Note No. 22. (V/F control large boost)

Maximum starting torque coefficient $\alpha_s = \boxed{1.1}$

Linear acceleration torque coefficient $\alpha_a = \boxed{1.1}$

Hot coefficient $\sigma = \boxed{0.85}$

(4) Operating frequency range of the temporarily selected inverter

According to $f = \dfrac{\text{motor speed} \times \text{number of motor poles}}{120}$

Frequency corresponding to the maximum speed

$$f_{max} = \frac{N_{max} \times P}{120} = \boxed{\frac{1800 \times 4}{120}} = \boxed{60} \text{ [Hz]}$$

Frequency corresponding to the minimum speed

$$f_{min} = \frac{N_{min} \times P}{120} = \boxed{\frac{180 \times 4}{120}} = \boxed{6} \text{ [Hz]}$$

2.4 Whether the Motor Can Be Started and Run at Low Speed or Not

(1) Motor starting torque $(T_{MS}) = T_M \times \alpha_s \times \sigma = \boxed{4.06 \times 1.1 \times 0.85} = \boxed{3.796}$

(For α_s and σ, refer to Technical Note No. 22.)

(2) Supposing that load torque at start (T_{LS}) = maximum load torque (T_{Lmax})

Analysis of whether the motor can be started or not

$T_{LS} = \boxed{2.573} < T_{MS} = \boxed{3.796}$ OK

(3) Short-time maximum torque at f_{min} (6Hz or more)

$T_{M1} = T_M \times \alpha_m \times \sigma = \boxed{4.06 \times 1.1 \times 0.85} = \boxed{3.796}$ [kgf•m]

(For α_m and σ, refer to Technical Note No. 22.)

Analysis of whether low-speed operation can be performed or not

$T_{LS} = \boxed{2.573} < T_{M1} = \boxed{3.796}$ OK

$T_{LS} = \boxed{2.573} < T_{MS} = \boxed{3.796}$

2.5 Whether Acceleration/Deceleration Is possible or Not

(1) Acceleration torque during lifting (T_{a1})

$$= \frac{(GD^2{}_L + GD^2{}_M + GD^2{}_B) \times N_{max}}{375 \times t_a} = \boxed{\frac{0.2459 \times 1800}{375 \times 1.0}} = \boxed{1.1803} \text{ [kgf•m]}$$

(2) Deceleration torque during lifting (T_{d1})

$$= \frac{(GD^2{}_L + GD^2{}_M + GD^2{}_B) \times N_{max}}{375 \times t_d} = \boxed{\frac{0.2459 \times 1800}{375 \times 1.0}} = \boxed{1.1803} \text{ [kgf•m]}$$

(3) Acceleration torque during lowering (T_{a2})

$$= \frac{(GD^2{}_{Ldn} + GD^2{}_M + GD^2{}_B) \times N_{max}}{375 \times t_a} = \boxed{\frac{0.2389 \times 1800}{375 \times 1.0}} = \boxed{1.1467} \text{ [kgf•m]}$$

(4) Deceleration torque during lowering (T_{d2})

$$= \frac{(GD^2{}_{Ldn} + GD^2{}_M + GD^2{}_B) \times N_{max}}{375 \times t_d} = \boxed{\frac{0.2389 \times 1800}{375 \times 1.0}} = \boxed{1.1467} \text{ [kgf•m]}$$

(5) Torque applied to the motor in each region

	Region	Torque applied to the motor [kgf•m]
Lifting	1)	$T_{aup} = T_{a1} + T_{LU} = \boxed{1.1803 + 2.573} = \boxed{3.753}$
	2)	$T_{LU} = \boxed{2.573}$
	3)	$T_{dup} = -T_{d1} + T_{LU} = \boxed{-1.1803 + 2.573} = \boxed{1.393}$
	4)	$T_{LU} = \boxed{2.573}$
Lowering	5)	$T_{adn} = T_{a2} + T_{LD} = \boxed{1.1467 - 1.463} = \boxed{-0.316}$
	6)	$T_{LD} = \boxed{-1.463}$
	7)	$T_{ddn} = -T_{a2} + T_{LD} = \boxed{-1.1467 - 1.463} = \boxed{-2.610}$
	8)	$T_{LD} = \boxed{-1.463}$

(6) Torque required for acceleration and deceleration

(a) Torque coefficient required for acceleration during lifting (α)

$$= \frac{Ta_{max}}{T_M} = \boxed{\frac{3.753}{4.06}} = \boxed{0.924}$$

Ta_{max} is either of Ta_{up} in region 1 and Ta_{dn} in region 5, which is larger.
Note that regenerative acceleration is made when $Ta_{up} < 0$ and $Ta_{dn} < 0$. In this case, the maximum torque required for regeneration is judged by whether deceleration is possible or not. Hence, the judgment of whether acceleration is possible or not is not needed here.

Analysis of whether acceleration is possible or not

$$\alpha_a \times \sigma = \boxed{1.1} \times \boxed{0.85} > \alpha = \boxed{0.924}$$

OK

αa: Linear acceleration torque coefficient (torque boost large)
δ: Heat coefficient (refer to Technical Note No. 22.)

(b) Torque coefficient required for deceleration during lowering (β)

$$= \frac{|Td_{max}|}{T_M} = \boxed{\frac{2.610}{4.06}} = \boxed{0.643}$$

Td_{max} is either of Td_{up} in region 3 and Td_{dn} in region 7, which is smaller.
Note that driving deceleration is made when $Td_{up} > 0$ and $Td_{dn} > 0$. In this case, the maximum torque required for driving is judged by whether acceleration is possible or not. Hence, the judgment of whether deceleration is possible or not is not needed here.

(c) Temporary selection of the brake unit

The torque type of the $\boxed{\text{FR-ABR-7.5K}}$ is $\boxed{\text{10B}}$.

<Refer to the braking capability data in Technical Note No. 22.>

Judgment of whether deceleration can be made or not

$$\beta_{min} = \boxed{1.0} > \beta = \boxed{0.643}$$

OK

β_{min}: Brake torque coefficient (minimum value)

2.6 Examination of Thermal Capacity of the Brake Unit

(1) Operation pattern

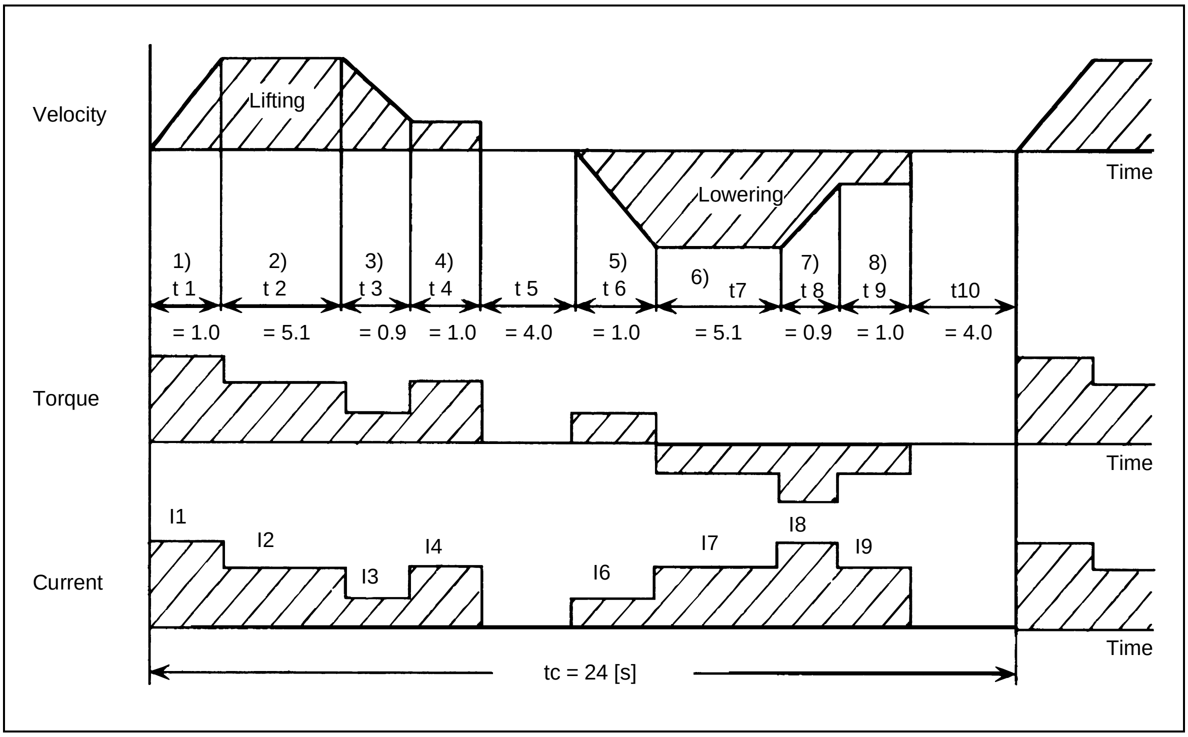


Fig. 4.4 Example of Operation Pattern

(2) Formulae for calculating torque and regenerative power in each operation zone

Zone	Regenerative Power [W]
1)	$W_1 = 1.027 \times \frac{N_1}{2} \times T_{aup} = \boxed{1.027 \times (1800 / 2) \times 3.753} = \boxed{3469}$
2)	$W_2 = 1.027 \times N_1 \times T_{LU} = \boxed{1.027 \times 1800 \times 2.573} = \boxed{4756}$
3)	$W_3 = 1.027 \times \frac{N_1 + N_2}{2} \times T_{dup} = \boxed{1.027 \times (1800 + 180) / 2 \times 1.393} = \boxed{1416}$
4)	$W_4 = 1.027 \times N_2 \times T_{LU} = \boxed{1.027 \times 180 \times 2.573} = \boxed{476}$
5)	$W_6 = 1.027 \times \frac{N_1}{2} \times T_{adn} = \boxed{1.027 \times (1800 / 2) \times (-0.316)} = \boxed{-292}$
6)	$W_7 = 1.027 \times N_1 \times T_{LD} = \boxed{1.027 \times 1800 \times (-1.463)} = \boxed{-2705}$
7)	$W_8 = 1.027 \times \frac{N_1 + N2}{2} \times T_{ddn} = \boxed{1.027 \times (1800 + 180) / 2 \times (-2.610)} = \boxed{-2654}$
8)	$W_9 = 1.027 \times N_2 \times T_{LD} = \boxed{1.027 \times 180 \times (-1.463)} = \boxed{-270}$

(3) Calculation of power

- Power returned from the load [W_{MECH}]

$$W_{MECH} = \frac{|\Sigma(W_n \times t_n)|}{\Sigma t_n}$$

From zones 1) to 8), calculate W_n and t_n only in the zones where power is negative.

$$= \boxed{\frac{|(-292)\times 1.0+(-2705)\times 5.1+(-2654)\times 0.9+(-270)\times 1.0|}{1.0+5.1+0.9+1.0}} = \boxed{2093}\ \text{[W]}$$

- Power returned to the inverter

$W_{INV} = W_{MECH} \times 0.9 = \boxed{2093 \times 0.9} = \boxed{1884}$ [W]

(4) Short-time permissible power per operation of the braking unit $W_{RS} = \boxed{16500}$ [W]
FR-BU-15K (8 seconds) (For W_{RS}, refer to Technical Note No. 22.)

Analysis of short-time permissible power

$W_{INV} = \boxed{1884} < W_{RS} = \boxed{16500}$

OK

(5) Checking the continuous average regenerative power

$$W_{INV} \times \frac{t_1 + t_2 + \Lambda + t_n}{t_c} = \boxed{1884 \times \frac{1.0 + 5.1 + 0.9 + 1.0}{24}} = \boxed{628}\ \text{[W]}$$

(t_1 to t_n is the sum total of times when power is negative in operation zones 1) to 8))

(6) Continuous permissible power W_{RC} (refer to Technical Note No. 22) = $\boxed{990}$ [W]

Analysis of continuous permissible power

$W_{INV} \times \frac{t}{t_c} = \boxed{628} < W_{RC} = \boxed{990}$

OK

(7) Checking the short-time permissible power in the continuous regenerative operation zone

$W_n \times 0.9 = \boxed{1884} < W_{RS}$ (for 8 seconds) = $\boxed{16500}$
(For W_{RS} during 8 seconds, for to Technical Note No. 22.)

2.7 Examination of Whether the Motor Can Be Used Thermally

(1) Required motor torque, load torque factor and current characteristic (%)

	Zone	Torque Supplied to the Load	Load Torque Factor [%]	Current Characteristic [%]	Cooling Coefficient
During rising	t_1	$T_{aup} = T_{a1} + T_{LU}$ = 3.753	TF = 92.4	I1 = 94	C1 = 0.76
	t_2	T_{LU} = 2.573		I2 = 72	C2 = 1.0
	t_4		TF = 63.4	I4 = 72	C4 = 0.4
	t_3	$T_{dup} = -T_{d1} + T_{LU}$ = 1.393	TF = 34.3	I3 = 59	C3 = 0.80
During falling	t_6	$T_{adn} = T_{a2} + T_{LD}$ = –0.316	TF = 7.8	I6 = 51	C6 = 0.76
	t_7	T_{LD} = –1.463		I7 = 60	C7 = 1.0
	t_9		TF = 36.0	I9 = 60	C9 = 0.4
	t_8	$T_{ddn} = -T_{d2} + T_{LD}$ = –2.610	TF = 64.2	I8 = 74	C8 = 0.80

Note: Motor torque used is the above calculated value.

(2) Motor equivalent current value (I_{MC})

$$I_{MC} = \sqrt{\frac{I_1^2 \times t_1 + I_2^2 \times t_2 \,.......+ I_n^2 \times t_n}{C_1 \times t_1 + C_2 \times t_2 + ...+ C_n \times t_n}}$$

$$= \sqrt{\frac{(94^2 \times 1 + 72^2 \times 5.1 + 59^2 \times 0.9 + 72^2 \times 1) + (51^2 \times 1 + 60^2 \times 5.1 + 74^2 \times 0.9 + 60^2 \times 1)}{(0.76 \times 1 + 10 \times 5.1 + 0.8 \times 0.9 + 0.4 \times 1 + 0.4 \times 4) + (0.76 \times 1 + 10 \times 5.1 + 0.8 \times 0.9 + 0.4 \times 1 + 0.4 \times 4)}}$$

$$= \sqrt{\frac{43591 + 29489}{8.58 + 8.58}} = \frac{270.3}{4.14} = \boxed{65.3} < 100\% \qquad \boxed{\text{OK}}$$

2.8 Examination of Stopping Accuracy

(1) Characteristics of the brake

According to Technical Note No. 22, the characteristics of the mechanical brake $\boxed{NB\text{-}7.5C}$ are:

- Rated braking torque : $T_B = \boxed{7.5}$ [kgf•m]
- Delay time (independent off) : $t_{01} = \boxed{0.036}$ [s]
- Brake GD^2 : $GD^2_B = \boxed{0.062}$ [kgf•m^2]

(2) Stopping accuracy when the motor running at low speed (creep speed) is brought to a stop

Stopping time (t_b) $= t_{01} + t_{11}$

$$= t_{01} + \frac{(GD_L^2 + GD_M^2 + GD_B^2) \times N_{min}}{375 \times (T_B + T_L)}$$

$$= \boxed{0.036} + \boxed{\frac{0.2389 \times 180}{375 \times (7.5 - 1.463)}}$$

$$= \boxed{0.036} + \boxed{0.019}$$

$$= \boxed{0.055}$$

where,

T_L : Load torque during lifting (T_{LU})

: Load torque during lowering (T_{LD})

Stopping distance (S) $= S_{01} + S_{11} = (t_{01} \times \frac{V_{min}}{60} + t_{11} \times \frac{V_{min}}{60} \times \frac{1}{2}) \times 10^3$

$$= (\boxed{0.036 \times 3/60} + \boxed{0.019 \times 3/60 \times 1/2}) \times 10^3$$

$$= \boxed{2.28} \text{ [mm]}$$

Guideline of stopping accuracy ($\Delta\varepsilon$) = ±S/2 = $\boxed{2.28/2}$ = ± $\boxed{1.14}$ [mm]

2.9 Determination of the Models

According to the above examination results, the recommended models are as follows:

Motor : 7.5kW 4P
Inverter : FR-A520-7.5K
(Control system: V/F control)
Braking unit : FR-BU-15K
FR-BR-15K

APPENDIX 1)

CALCULATION SHEETS <SI Systems of Units>

1. Machine Conditions Required for Examination

(1) Voltage and frequency of the power supply [V] [Hz]

(2) Required power P_L (When unknown, refer 2.2.) [kW]

(3) Operating speed range of the motor N_{min} to N_{max} [r/min]

(4) Number of motor poles P

(5) Operating frequency range f_{min} to f_{max} [Hz]

(6) Weight of the drive section W

(a) Lift table's own weight W_T [kgf]

(b) Lifter load during lifting W_{Lup} [kgf]

(c) Lifter load during lowering W_{Ldn} [kgf]

(d) Counterweight W_C [kgf]

(e) Chain weight W_{CH} [kgf]

(f) Chain eccentric load W_{CS} [kgf]

(g) Pulley average diameter D_S [m]

(h) Pulley-rope friction coefficient μ

(7) Lifting velocity V_{min} to V_{max} [m/min]

(8) Machine efficiency of the drive section η

(9) Load torque converted into the equivalent value at the motor shaft

(a) Load torque during lifting T_{LU} (When unknown, refer 2.1.) [N•m]

(b) Load torque during lowering T_{LD} (When unknown, refer 2.1.) [N•m]

Hence, make the following calculation on the assumption that maximum torque

T_{Lmax} = [N•m].

(10) Load GD^2 converted into the equivalent value at the motor shaft

(a) GD^2 of the lift case GD^2_{WT} (When unknown, refer 2.1.) [kgf•m²]

(b) Lifter load during lifting GD^2_{WLup} (When unknown, refer 2.1.) [kgf•m²]

(c) Lifter load during lowering GD^2_{WLdn} (When unknown, refer 2.1.) [kgf•m²]

(d) GD^2 of the counterweight GD^2_{WC} (When unknown, refer 2.1.) [kgf•m²]

(e) Chain weight GD^2_{WCH} (When unknown, refer 2.1.) [kgf•m²]

(f) GD^2 of the mechanical brake GD^2_B, etc. [kgf•m²]

Total load converted into the equivalent value at the motor shaft during lifting GD^2_{Lup}

$= \{GD^2_{WT} + GD^2_{WLup} + GD^2_{WC} + GD^2_{WCH}\}$

= + + +

= [kgf•m²]

Total load converted into the equivalent value at the motor shaft during lowering GD^2_{Ldn}

$= \{GD^2_{WT} + GD^2_{WLdn} + GD^2_{WC} + GD^2_{WCH}\}$

= + + +

= [kgf•m²]

(11) Operation pattern

(a) Acceleration time ta [s]
(b) Deceleration time td [s]
(c) Time of one cycle tc [s]

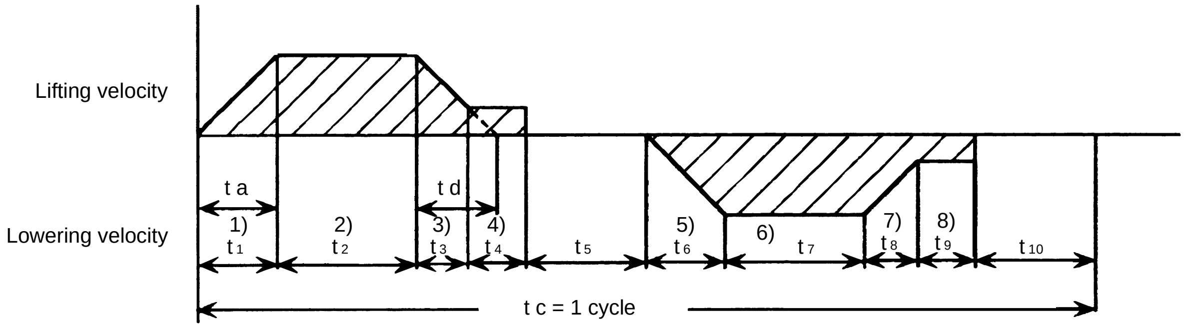


Fig. App.1 General Structure of the Lift

2.1 Calculation of Load Specifications Required for Calculation

(1) Pulley speed (N_2)

$N_2 = V/(\pi \times D_S) = \boxed{\quad / (\quad \times \quad)} = \boxed{\qquad}$ [r/min]

(2) Reduction ratio of the reduction gear (n)

Supposing that the motor is $\boxed{\qquad}$ P and is run at $\boxed{\qquad}$ Hz, $N_1 = \boxed{\qquad}$ [r/min]

$n = N_1/N_2 = \boxed{\quad / \quad} = \boxed{\qquad}$

(3) Moving distance of the lift per motor revolution (ΔS)

$$\Delta S = \frac{\pi \times Ds}{n} \times 10^3 = \frac{\pi \times \boxed{\qquad}}{\boxed{\qquad}} \times 10^3 = \boxed{\qquad} \quad [\text{mm}]$$

(4) Calculation of load GD^2

(a) GD^2_{WT} of the lift table

$GD^2_{WT} = W_{LB} \times (V/\pi N_1)^2$

$= \boxed{\qquad\qquad} = \boxed{\qquad}$ [kgf•m^2]

(b) GD^2_{WLup} of lifter load during lifting

$GD^2_{WLup} = W_{Lup} \times (V/\pi N_1)^2$

$= \boxed{\qquad\qquad} = \boxed{\qquad}$ [kgf•m^2]

(c) GD^2_{WLdn} of lifter load during lowering

$GD^2_{WLdn} = W_{Ldn} \times (V/\pi N_1)^2$

$= \boxed{\qquad\qquad} = \boxed{\qquad}$ [kgf•m^2]

(d) GD^2_{WC} of the counterweight

$GD^2_{WC} = W_C \times (V/\pi N_1)^2$

$= \boxed{\qquad\qquad} = \boxed{\qquad}$ [kgf•m^2]

(e) GD^2_{CH} of chain

$GD^2_{CH} = W_{CH} \times (V/\pi N_1)^2$

$= \boxed{\qquad\qquad} = \boxed{\qquad}$ [kgf•m^2]

Total load converted into the equivalent value at the motor shaft during lifting

$GD^2_{Lup} = GD^2_{WT} + GD^2_{WLup} + GD^2_{WC} + GD^2_{WCH}$

$= \boxed{\qquad} + \boxed{\qquad} + \boxed{\qquad} + \boxed{\qquad}$

$= \boxed{\qquad}$ [kgf•m^2]

Total load converted into the equivalent value at the motor shaft during lowering

$GD^2_{Ldn} = GD^2_{WT} + GD^2_{WLdn} + GD^2_{WC} + GD^2_{WCH}$

$= \boxed{\qquad} + \boxed{\qquad} + \boxed{\qquad} + \boxed{\qquad}$

$= \boxed{\qquad}$ [kgf•m^2]

(5) Calculation of load torque converted into the equivalent value at the motor shaft (T_L)

(a) During lifting

$(W_T + W_{Lup}) \geq W_C$: $W_{up} = (W_T + W_{Lup} + W_{CS}) - W_C$

$$= \boxed{\qquad\qquad\qquad} = \boxed{\qquad\qquad} \text{ [kgf]}$$

$(W_T + W_{Lup}) < W_C$: $W_{up} = (W_T + W_{Lup}) - (W_C + W_{CS})$

$$= \boxed{\qquad\qquad\qquad} = \boxed{\qquad\qquad} \text{ [kgf]}$$

- When $W_{up} \geq 0$

$T_{LU} = T_{Uup} + Tfr_{up}$

$$= \frac{W_{up} \times \Delta S \times 10^{-3}}{2 \times \pi \times \eta} + \frac{\mu \times Wa_{up} \times \Delta S \times 10^{-3}}{2 \times \pi \times \eta}$$

$$= \boxed{\frac{\qquad\qquad}{\qquad\qquad}} + \boxed{\frac{\qquad\qquad}{\qquad\qquad}}$$

$$= \boxed{\qquad\qquad} + \boxed{\qquad\qquad} = \boxed{\qquad\qquad} \text{ [N•m]}$$

- When $W_{up} < 0$ (To take safety into consideration, make calculation by setting the machine efficiency (η) to 1 and the friction coefficient (μ) to 0.)

$T_{LU} = T_{Uup} \times \eta^2 + Tfr_{up}$

$$= \boxed{\frac{W_{up} \times \Delta S \times 10^{-3}}{2 \times \pi \times 1.0}} \times 1^2 + \boxed{\frac{0 \times Wa_{up} \times \Delta S \times 10^{-3}}{2 \times \pi \times 1.0}}$$

$$= \boxed{\frac{\qquad\qquad}{\qquad\qquad}} \times 1^2 + 0 = \boxed{\qquad\qquad} \text{ [N•m]}$$

where,
T_{Uup} : Unbalance torque during lifting [N•m]
Tfr_{up} : Friction torque of drive section during lifting [N•m]
Wa_{up} : Total weight during lifting [kgf]

(b) During lowering

$(W_T + W_{Ldn}) \geq W_C$: $W_{dn} = W_C - (W_T + W_{Ldn} + W_{CS})$

$= \boxed{\qquad\qquad\qquad\qquad} = \boxed{\qquad\qquad}$ [kgf]

$(W_T + W_{Ldn}) < W_C$: $W_{dn} = (W_C + W_{CS}) - (W_T + W_{Ldn})$

$= \boxed{\qquad\qquad\qquad\qquad} = \boxed{\qquad\qquad}$ [kgf]

- When $W_{dn} \geq 0$

$T_{LD} = T_{Udn} + Tfr_{dn}$

$$= \frac{W_{dn} \times \Delta S \times 10^{-3}}{2 \times \pi \times \eta} + \frac{\mu \times Wa_{dn} \times \Delta S \times 10^{-3}}{2 \times \pi \times \eta}$$

$$= \boxed{\frac{\qquad\qquad}{\qquad\qquad}} + \boxed{\frac{\qquad\qquad}{\qquad\qquad}}$$

$$= \boxed{\frac{\qquad}{\qquad}} + \boxed{\frac{\qquad}{\qquad}} = \boxed{\frac{\qquad}{\qquad}} \text{ [N•m]}$$

- When $W_{dn} < 0$ (To take safety into consideration, make calculation by setting the machine efficiency (η) to 1 and the friction coefficient (μ) to 0.)

$T_{LD} = T_{Udn} \times \eta^2 + Tfr_{dn}$

$$= \boxed{\frac{W_{dn} \times \Delta S \times 10^{-3}}{2 \times \pi \times \eta}} \times 1^2 + \boxed{\frac{0 \times Wa_{dn} \times \Delta S \times 10^{-3}}{2 \times \pi \times \eta}}$$

$$= \boxed{\frac{\qquad\qquad}{\qquad\qquad}} \times 1^2 + 0 = \boxed{\qquad\qquad} \text{ [N•m]}$$

where, T_{Udn} : Unbalance torque during lowering [N•m]
Tfr_{dn} : Friction torque of drive section during lowering [N•m]
Wa_{dn} : Total weight during lowering [kgf]

Hence, make the following calculation with the max. load torque (T_{Lmax}) = $\boxed{\qquad\qquad}$ [N•m].

2.2 Selection of motor capacity

(1) Required power of the load

$P_L = \frac{W \times V}{6120 \times \eta}$ (W is larger of $|W_{up}|$ and $|W_{dn}|$)

$= \boxed{\frac{\qquad}{\qquad}} = \boxed{\quad}$ [kW]

(2) Temporary selection of motor capacity (P_M)

$P_M = \alpha p \times P_L$ (αp= 0.5 to 2.0)

$= \boxed{\quad} \times \boxed{\quad} = \boxed{\quad}$ [kW] ⇒ Select $\boxed{\quad}$ [kW].

(3) GD^2 of the motor, etc.

Motor $GD^2_M = \boxed{\quad}$ [kgf•m^2] (For the kW P motor)

(4) GD^2_B of the mechanical brake

Motor $GD^2_B = \boxed{\quad}$ [kgf•m^2] Note that the brake is the NB-$\boxed{\quad}$.

Total GD^2_{up} converted into the equivalent value at the motor shaft during lifting is:

$GD^2_{up} = GD^2_M + GD^2_B + GD^2_{Lup} = \boxed{\quad} + \boxed{\quad} + \boxed{\quad}$

$= \boxed{\quad}$ [kgf•m^2]

Total GD^2_{dn} converted into the equivalent value at the motor shaft during lowering is:

$GD^2_{dn} = GD^2_M + GD^2_B + GD^2_{Ldn} = \boxed{\quad} + \boxed{\quad} + \boxed{\quad}$

$= \boxed{\quad}$ [kgf•m^2]

2.3 Temporary selection of inverter capacity

(1) Rated torque (T_M) of the temporarily selected motor (60Hz rating basis)

$T_M = \frac{9550 \times P_M}{N_M} = \boxed{\frac{\qquad}{\qquad}} = \boxed{\quad}$ [N•m]

(2) Temporary selection of the inverter capacity

According to the motor capacity, select the $\boxed{\text{FR-}\qquad}$.

(3) Determination of the torque type

According to the motor and inverter temporarily selected, the torque type is $\boxed{\quad}$ with reference to Technical Note No. 22. (Magnetic flux vector control)

Maximum starting torque coefficient $\alpha_s = \boxed{\quad}$

Linear acceleration torque coefficient $\alpha_a = \boxed{\quad}$

Heat coefficient $\sigma = \boxed{\quad}$

(4) Operating frequency range of the temporarily selected inverter

According to $f = \frac{\text{motor speed} \times \text{number of motor poles}}{120}$

Frequency corresponding to the maximum speed

$f_{max} = \frac{N_{max} \times P}{120} = \boxed{\frac{\qquad}{\qquad}} = \boxed{\quad}$ [Hz]

Frequency corresponding to the minimum speed

$f_{min} = \frac{N_{min} \times P}{120} = \boxed{\frac{\qquad}{\qquad}} = \boxed{\quad}$ [Hz]

2.4 Whether the Motor Can Be Started and Run at Low Speed or Not

(1) Motor starting torque (T_{MS}) = $T_M \times \alpha_s \times \sigma$ = ☐ = ☐ [N•m]

(For α_s and σ, refer to Technical Note No. 22.)

(2) Supposing that load torque at start (T_{LS}) = maximum load torque (T_{Lmax})

Analysis of whether the motor can be started or not

T_{LS} = ☐ < T_{MS} = ☐

OK
NG

(3) When the inverter is made one rank higher ☐ and examination is made again:

- Torque type ☐
- Maximum starting torque coefficient α_S = ☐
- Linear acceleration torque coefficient α_a = ☐
- Heat coefficient σ = ☐

$T_{MS} = T_M \times \alpha_S \times \sigma$ = ☐ = ☐

Analysis of whether the motor can be started or not

T_{LS} = ☐ < T_{MS} = ☐

OK
NG

(4) Short-time maximum torque at f_{min} (6Hz or more)

$T_{M1} = T_M \times \alpha_m \times \sigma$ = ☐ = ☐ [N•m]

(For α_m and σ, refer to Technical Note No. 22.)

Analysis of whether low-speed operation can be performed or not

T_{LS} = ☐ < T_{M1} = ☐

T_{LS} = ☐ < T_{MS} = ☐

OK
NG

2.5 Whether Acceleration/Deceleration is Possible or Not

(1) Acceleration torque during lifting (T_{a1})

$$= \frac{(GD^2{}_{Lup} + GD^2{}_{M} + GD^2{}_{B}) \times N_{max}}{38.2 \times t_a} = \boxed{\frac{\qquad\qquad}{\qquad\qquad}} = \boxed{\qquad\qquad} \ [\text{N•m}]$$

(2) Deceleration torque during lifting (T_{d1})

$$= \frac{(GD^2{}_{Lup} + GD^2{}_{M} + GD^2{}_{B}) \times N_{max}}{38.2 \times t_d} = \boxed{\frac{\qquad\qquad}{\qquad\qquad}} = \boxed{\qquad\qquad} \ [\text{N•m}]$$

(3) Acceleration torque during lowering (T_{a2})

$$= \frac{(GD^2{}_{Ldn} + GD^2{}_{M} + GD^2{}_{B}) \times N_{max}}{38.2 \times t_a} = \boxed{\frac{\qquad\qquad}{\qquad\qquad}} = \boxed{\qquad\qquad} \ [\text{N•m}]$$

(4) Deceleration torque during lowering (T_{d2})

$$= \frac{(GD^2{}_{Ldn} + GD^2{}_{M} + GD^2{}_{B}) \times N_{max}}{38.2 \times t_d} = \boxed{\frac{\qquad\qquad}{\qquad\qquad}} = \boxed{\qquad\qquad} \ [\text{N•m}]$$

(5) Torque applied to the motor in each region

	Region	Torque applied to the motor [N•m]
Lifting	1)	$T_{aup} = T_{a1} + T_{LU} = \boxed{\qquad\qquad} = \boxed{\qquad\qquad}$
	2)	$T_{LU} = \boxed{\qquad\qquad}$
	3)	$T_{dup} = -T_{d1} + T_{LU} = \boxed{\qquad\qquad} = \boxed{\qquad\qquad}$
	4)	$T_{LU} = \boxed{\qquad\qquad}$
Lowering	5)	$T_{adn} = T_{a2} + T_{LD} = \boxed{\qquad\qquad} = \boxed{\qquad\qquad}$
	6)	$T_{LD} = \boxed{\qquad\qquad}$
	7)	$T_{ddn} = -T_{a2} + T_{LD} = \boxed{\qquad\qquad} = \boxed{\qquad\qquad}$
	8)	$T_{LD} = \boxed{\qquad\qquad}$

(6) Torque required for acceleration and deceleration

(a) Torque coefficient required for acceleration during rising (α)

$$= \frac{Ta_{max}}{T_M} = \boxed{\frac{\qquad\qquad}{\qquad\qquad}} = \boxed{\qquad}$$

Ta_{max} is either of Ta_{up} in region 1 and Ta_{dn} in region 5, which is larger.
Note that regenerative acceleration is made when $Ta_{up} < 0$ and $Ta_{dn} < 0$. In this case, the maximum torque required for regenerative acceleration is judged by whether deceleration is possible or not. Hence, the judgment of whether acceleration is possible or not is not needed here.

Analysis of whether acceleration is possible or not

OK
NG

$\alpha_a \times \sigma = \boxed{\qquad} \times \boxed{\qquad} > \alpha = \boxed{\qquad}$

α_a: Linear acceleration torque coefficient (torque boost large)
σ: Heat coefficient (refer to Technical Note No. 22.)

(b) Torque coefficient required for deceleration during falling (β)

$$= \frac{|Td_{max}|}{T_M} = \boxed{\frac{\qquad\qquad}{\qquad\qquad}} = \boxed{\qquad}$$

Td_{max} is either of Td_{up} in region 3 and Td_{dn} in region 7, which is smaller.
Note that driving deceleration is made when $Td_{up} > 0$ and $Td_{dn} > 0$. In this case, the maximum torque required for driving deceleration is judged by whether acceleration is possible or not. Hence, the judgment of whether deceleration is possible or not is not needed here.

(c) Temporary selection of the brake unit

The torque type of the $\boxed{\qquad}$ is $\boxed{\qquad}$.
<Refer to the braking capability data in Technical Note No. 22.>

Analysis of whether deceleration is possible or not

OK
NG

$\beta_{min} = \boxed{\qquad} > \beta = \boxed{\qquad}$

β_{min}: Brake torque coefficient (minimum value)

2.6 Examination of Thermal Capacity of the Brake Unit

(1) Operation pattern

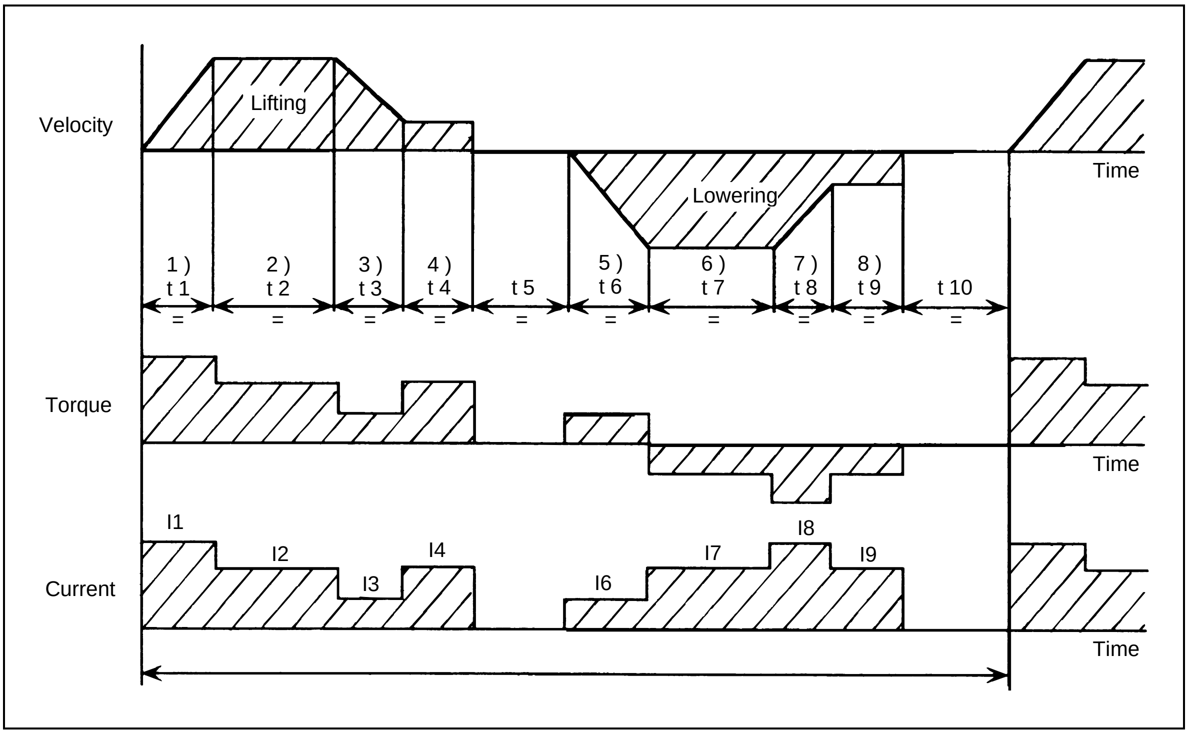


Fig. App.2 Example of Operation Pattern

(2) Formulae for calculating and regenerative power in each operation zone

Zone	Regenerative Power [W]
1)	$W_1 = 0.1047 \times \frac{N_1}{2} \times T_{aup} = \boxed{} = \boxed{}$
2)	$W_2 = 0.1047 \times N_1 \times T_{LU} = \boxed{} = \boxed{}$
3)	$W_3 = 0.1047 \times \frac{N_1 + N_2}{2} \times T_{dup} = \boxed{} = \boxed{}$
4)	$W_4 = 0.1047 \times N_2 \times T_{LU} = \boxed{} = \boxed{}$
5)	$W_6 = 0.1047 \times \frac{N_1}{2} \times T_{adn} = \boxed{} = \boxed{}$
6)	$W_7 = 0.1047 \times N_1 \times T_{LD} = \boxed{} = \boxed{}$
7)	$W_8 = 0.1047 \times \frac{N_1 + N_2}{2} \times T_{ddn} = \boxed{} = \boxed{}$
8)	$W_9 = 0.1047 \times N_2 \times T_{LD} = \boxed{} = \boxed{}$

(3) Calculation of power

- Power returned from the load [W_{MECH}]

$$W_{MECH} = \frac{\left|\Sigma(W_n \times t_n)\right|}{\Sigma t_n}$$

From zones 1) to 8), calculate W_n and t_n only in the zones where power is negative.

$$= \boxed{\frac{\qquad\qquad}{\qquad\qquad}} = \boxed{\qquad} \text{ [W]}$$

- Power returned to the inverter

$W_{INV} = W_{MECH} \times 0.9 = \boxed{\qquad} = \boxed{\qquad}$ [W]

(4) Short-time permissible power per operation of the braking unit $W_{RS} = \boxed{\qquad}$ [W]

(For W_{RS}, refer to the Technical Note No. 22.)

Analysis of short-time permissible power

$W_{INV} = \boxed{\qquad} < W_{RS} = \boxed{\qquad}$

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(5) Checking the continuous average regenerative power

$$W_{INV} \times \frac{t_1 + t_2 + \Lambda + t_n}{t_c} = \boxed{\quad \times \frac{\qquad\qquad}{\qquad\qquad}} = \boxed{\qquad} \text{ [W]}$$

(t_1 to t_n is the sum total of times when power is negative in operation zones 1) to 8))

(6) Continuous permissible power W_{RC} (refer to Technical Note No. 22) = $\boxed{\qquad}$ [W]

Analysis of continuous permissible power

$W_{INV} \times \frac{t}{t_c} = \boxed{\qquad} < W_{RC} = \boxed{\qquad}$

OK
NG

(7) Checking the short-time permissible power in the continuous regenerative operation zone

$W_n \times 0.9 = \boxed{\qquad} < W_{RS}$ (for seconds) = $\boxed{\qquad}$

(For W_{RS} for seconds, refer to Technical Note No. 22.)

2.7 Examination of Whether the Motor Can Be Used Thermally

(1) Required motor torque, load torque factor and current characteristic (%)

	Zone	Torque Supplied to the Load	Load Torque Factor [%]	Current Characteristic [%]	Cooling Coefficient
During rising	t_1	$T_{aup} = T_{a1} + T_{LU}$ $=$ ☐	TF = ☐	I1 = ☐	C1 = ☐
	t_2	$T_{LU} =$ ☐		I2 = ☐	C2 = ☐
	t_4		TF = ☐	I4 = ☐	C4 = ☐
	t_3	$T_{dup} = -T_{d1} + T_{LU}$ $=$ ☐	TF = ☐	I3 = ☐	C3 = ☐
During falling	t_6	$T_{adn} = T_{a2} - T_{LD}$ $=$ ☐	TF = ☐	I6 = ☐	C6 = ☐
	t_7	$T_{LD} =$ ☐		I7 = ☐	C7 = ☐
	t_9		TF = ☐	I9 = ☐	C9 = ☐
	t_8	$T_{ddn} = -T_{d2} + T_{LD}$ $=$ ☐	TF = ☐	I8 = ☐	C8 = ☐

Note: Motor torque used is the above calculated value.

(2) Motor equivalent current value I_{MC}

$$I_{MC} = \sqrt{\frac{I_1^2 \times t_1 + I_2^2 \times t_2 ....+ I_n^2 \times t_n}{C_1 \times t_1 + C_2 \times t_2 + ...+ C_n \times t_n}}$$

$$= \sqrt{\frac{\qquad}{\qquad}}$$

$$= \sqrt{\frac{\qquad}{\qquad}} = \frac{\quad}{\quad} = \boxed{} < 100\%$$

2.8 Examination of Stopping Accuracy

(1) Characteristics of the brake

According to Technical Note No. 22, the characteristics of the mechanical brake $\boxed{}$ are:

- Rated braking torque : T_B = $\boxed{}$ [N•m]
- Delay time (independent off) : t_{01} = $\boxed{}$ [s]
- Brake GD^2 : GD^2_B = $\boxed{}$ [kgf•m^2]

(2) Stopping accuracy when the motor is running at a slow speed (creep speed), and is brought to a stop

Stopping time (t_b)

$$= t_{01} + t_{11}$$

$$= t_{01} + \frac{(GD_L^2 + GD_M^2 + GD_B^2) \times N_{min}}{38.2 \times (T_B + T_L)}$$

$$= \boxed{} + \boxed{\frac{\qquad\qquad}{\qquad\qquad}}$$

$$= \boxed{} + \boxed{}$$

$$= \boxed{} \text{ [s]}$$

where,
T_L : Load torque during rising (T_{LU})
: Load torque during falling (T_{LD})

Stopping distance (S) $= S_{01} + S_{11} = (t_{01} \times \frac{V_{min}}{60} + t_{11} \times \frac{V_{min}}{60} \times \frac{1}{2}) \times 10^3$

$$= (\boxed{} + \boxed{}) \times 10^3$$

$$= \boxed{} \text{ [mm]}$$

Guideline of stopping accuracy ($\Delta\varepsilon$) = ±S/2 = $\boxed{/2}$ = ± $\boxed{}$ [mm]

2.9 Determination of the Models

According to the above examination results, the recommended models are as follows:

Motor : kW P
Inverter : FR-
(Control system:)
Braking unit :

APPENDIX 2)

CALCULATION SHEETS < Gravitational Systems of Units>

1. Machine Conditions Required for Examination

(1) Voltage and frequency of the power supply [V] [Hz]

(2) Required power P_L (When unknown, refer 2.2.) [kW]

(3) Operating speed range of the motor N_{min} to N_{max} [rpm]

(4) Number of motor poles P

(5) Operating frequency range f_{min} to f_{max} [Hz]

(6) Weight of the drive section W

- (a) Lift table's own weight W_T [kgf]
- (b) Lifter load during lifting W_{Lup} [kgf]
- (c) Lifter load during lowering W_{Ldn} [kgf]
- (d) Counterweight W_C [kgf]
- (e) Chain weight W_{CH} [kgf]
- (f) Chain eccentric load W_{CS} [kgf]
- (g) Pulley average diameter D_S [m]
- (h) Pulley-rope friction coefficient μ

(7) Lifting velocity V_{min} to V_{max} [m/min]

(8) Machine efficiency of the drive section η

(9) Load torque converted into the equivalent value at the motor shaft

- (a) Load torque during lifting T_{LU} (When unknown, refer 2.1.) [kgf•m]
- (b) Load torque during lowering T_{LD} (When unknown, refer 2.1.) [kgf•m]

Hence, make the following calculation on the assumption that maximum torque

T_{Lmax} = [kgf•m].

(10) Load GD^2 converted into the equivalent value at the motor shaft

- (a) GD^2 of the lift case GD^2_{WT} (When unknown, refer 2.1.) [kgf•m²]
- (b) GD^2 of the lift load GD^2_{WL} (When unknown, refer 2.1.) [kgf•m²]
- (c) Lifter load during lowering GD^2_{Wdn} (When unknown, refer 2.1.) [kgf•m²]
- (d) GD^2 of the counterweight GD^2_{WC} (When unknown, refer 2.1.) [kgf•m²]
- (e) Chain weight GD^2_{WCH} (When unknown, refer 2.1.) [kgf•m²]
- (f) GD^2 of the mechanical brake GD^2_B, etc. [kgf•m²]

Total load converted into the equivalent value at the motor shaft during lifting GD^2_{Lup}

$= \{GD^2_{WT} + GD^2_{WLup} + GD^2_{WC} + GD^2_{WCH}\}$

= + + +

= [kgf•m²]

Total load converted into the equivalent value at the motor shaft during lowering GD^2_{Ldn}

$= \{GD^2_{WT} + GD^2_{WLdn} + GD^2_{WC} + GD^2_{WCH}\}$

= + + +

= [kgf•m²]

(11) Operation pattern

(a) Acceleration time ta ☐ [s]
(b) Deceleration time td ☐ [s]
(c) Time of one cycle tc ☐ [s]

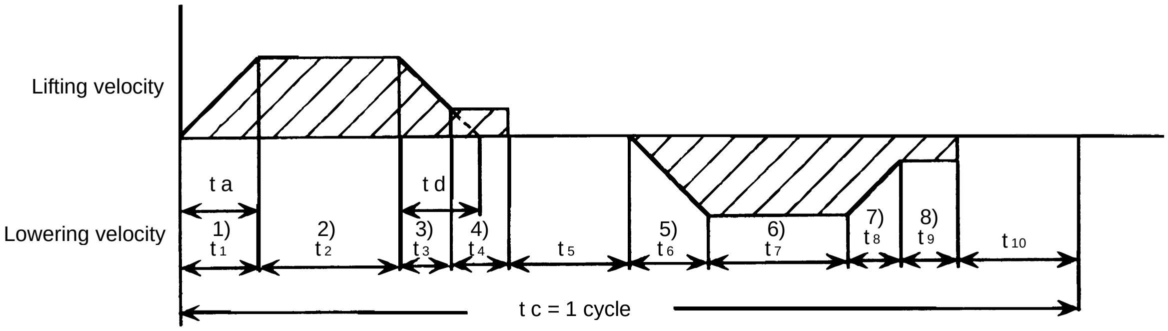

Fig. App.3 General Structure of the Lift

2.1 Calculation of Load

(1) Pulley speed (N_2)

$N_2 = V/(\pi \times D_S) = \boxed{\quad / (\quad \times \quad)} = \boxed{}$ [rpm]

(2) Reduction ratio of the reduction gear (n)

Supposing that the motor is $\boxed{}$ P and is run at $\boxed{}$ Hz, $N_1 = \boxed{}$ [rpm]

$n = N_1/N_2 = \boxed{\quad / \quad} = \boxed{}$

(3) Moving distance of the lift per motor revolution (ΔS)

$$\Delta S = \frac{\pi \times Ds}{n} \times 10^3 = \frac{\pi \times \boxed{}}{\boxed{}} \times 10^3 = \boxed{} \quad \text{[mm]}$$

(4) Calculation of load GD^2

(a) GD^2_{WT} of the lift case

$GD^2_{WT} = W_{LB} \times (V/\pi N_1)^2$

$= \boxed{} = \boxed{}$ [kgf•m²]

(b) GD^2_{WLup} of lifter load during lifting

$GD^2_{WLup} = W_L \times (V/\pi N_1)^2$

$= \boxed{} = \boxed{}$ [kgf•m²]

(c) GD^2_{WLdn} of lifter load during lowering

$GD^2_{WLdn} = W_{Ldn} \times (V/\pi N_1)^2$

$= \boxed{} = \boxed{}$ [kgf•m²]

(d) GD^2_{WC} of the counterweight

$GD^2_{WC} = W_C \times (V/\pi N_1)^2$

$= \boxed{} = \boxed{}$ [kgf•m²]

(e) GD^2_{CH} of chain

$GD^2_{CH} = W_{CH} \times (V/\pi N_1)^2$

$= \boxed{} = \boxed{}$ [kgf•m²]

Total load converted into the equivalent value at the motor shaft during lifting

$GD^2_{Lup} = GD^2_{WT} + GD^2_{WLup} + GD^2_{WC} + GD^2_{WCH}$

$= \boxed{} + \boxed{} + \boxed{} + \boxed{}$

$= \boxed{}$ [kgf•m²]

Total load converted into the equivalent value at the motor shaft during lowering

$GD^2_{Ldn} = GD^2_{WT} + GD^2_{WLdn} + GD^2_{WC} + GD^2_{WCH}$

$= \boxed{} + \boxed{} + \boxed{} + \boxed{}$

$= \boxed{}$ [kgf•m²]

(5) Calculation of load torque converted into the equivalent value at the motor shaft (T_L)

(a) During lifting

$(W_T + W_{Lup}) \geq W_C$: $W_{up} = (W_T + W_{Lup} + W_{CS}) - W_C$

$$= \boxed{\qquad\qquad\qquad\qquad} = \boxed{\qquad\qquad} \text{ [kgf]}$$

$(W_T + W_{Lup}) < W_C$: $W_{up} = (W_T + W_{Lup}) - (W_C + W_{CS})$

$$= \boxed{\qquad\qquad\qquad\qquad} = \boxed{\qquad\qquad} \text{ [kgf]}$$

- When $W_{up} \geq 0$

$T_{LU} = T_{Uup} + Tfr_{up}$

$$= \frac{W_{up} \times \Delta S \times 10^{-3}}{2 \times \pi \times \eta} + \frac{\mu \times Wa_{up} \times \Delta S \times 10^{-3}}{2 \times \pi \times \eta}$$

$$= \boxed{\frac{\qquad\qquad\qquad}{\qquad\qquad\qquad}} + \boxed{\frac{\qquad\qquad\qquad}{\qquad\qquad\qquad}}$$

$$= \boxed{\qquad\qquad} + \boxed{\qquad\qquad} = \boxed{\qquad\qquad} \text{ [kgf•m]}$$

- When $W_{up} < 0$ (To take safety into consideration, make calculation by setting the machine efficiency (η) to 1 and the friction coefficient (μ) to 0.)

$T_{LU} = T_{Uup} \times \eta^2 + Tfr_{up}$

$$= \boxed{\frac{W_{up} \times \Delta S \times 10^{-3}}{2 \times \pi \times 1.0}} \times 1^2 + \boxed{\frac{0 \times Wa_{up} \times \Delta S \times 10^{-3}}{2 \times \pi \times 1.0}}$$

$$= \boxed{\frac{\qquad\qquad\qquad}{\qquad\qquad\qquad}} \times 1^2 + 0 = \boxed{\qquad\qquad} \text{ [kgf•m]}$$

where,
T_{Uup} : Unbalance torque during lifting [kgf•m]
Tfr_{up} : Friction torque of drive section during lifting [kgf•m]
Wa_{up} : Total weight during lifting [kgf]

(b) During lowering

$(W_T + W_{Ldn}) \geq W_C$: $W_{dn} = W_C - (W_T + W_{Ldn} + W_{CS})$

$= \boxed{\qquad\qquad\qquad\qquad} = \boxed{\qquad\qquad}$ [kgf]

$(W_T + W_{Ldn}) < W_C$: $W_{dn} = (W_C + W_{CS}) - (W_T + W_{Ldn})$

$= \boxed{\qquad\qquad\qquad\qquad} = \boxed{\qquad\qquad}$ [kgf]

- When $W_{dn} \geq 0$

  $$T_{LD} = T_{Udn} + Tfr_{dn}$$

  $$= \frac{W_{dn} \times \Delta S \times 10^{-3}}{2 \times \pi \times \eta} + \frac{\mu \times Wa_{dn} \times \Delta S \times 10^{-3}}{2 \times \pi \times \eta}$$

  $$= \boxed{\frac{\qquad\qquad}{\qquad\qquad}} + \boxed{\frac{\qquad\qquad}{\qquad\qquad}}$$

  $$= \boxed{\qquad\qquad} + \boxed{\qquad\qquad} = \boxed{\qquad\qquad} \text{ [kgf•m]}$$

- When $W_{dn} < 0$ (To take safety into consideration, make calculation by setting the machine efficiency (η) to 1 and the friction coefficient (μ) to 0.)

  $$T_{LD} = T_{Udn} \times \eta^2 + Tfr_{dn}$$

  $$= \boxed{\frac{W_{dn} \times \Delta S \times 10^{-3}}{2 \times \pi \times 1.0}} \times 1^2 + \boxed{\frac{0 \times Wa_{dn} \times \Delta S \times 10^{-3}}{2 \times \pi \times 1.0}}$$

  $$= \boxed{\frac{\qquad\qquad}{\qquad\qquad}} \times 1^2 + 0 = \boxed{\qquad\qquad} \text{ [kgf•m]}$$

  where, T_{Udn} : Unbalance torque during lowering [kgf•m]
  Tfr_{dn} : Friction torque of drive section during lowering [kgf•m]
  Wa_{dn} : Total weight during lowering [kgf]

  Hence, make the following calculation with the max. load torque (T_{Lmax}) = $\boxed{\qquad\qquad}$ [kgf•m].

2.2 Selection of motor capacity

(1) Required power of the load

$P_L = \dfrac{W \times V}{6120 \times \eta}$ (W is larger of $|W_{up}|$ and $|W_{dn}|$)

$= \boxed{\dfrac{\qquad\qquad}{\qquad\qquad}} = \boxed{\qquad}$ [kW]

(2) Temporary selection of motor capacity (P_M)

$P_M = \alpha p \times P_L$ (αp= 0.5 to 2.0)

$= \boxed{\qquad} \times \boxed{\qquad} = \boxed{\qquad}$ [kW] ⇒ Select $\boxed{\qquad}$ [kW].

(3) GD^2 of the motor, etc.

Motor $GD^2_M = \boxed{\qquad}$ [kgf•m^2] (For the kW P motor)

(4) GD^2_B of the mechanical brake

$GD^2_B = \boxed{\qquad}$ [kgf•m^2] Note that the brake is the NB-$\boxed{\qquad}$.

Total GD^2_{up} converted into the equivalent value at the motor shaft during lifting is:

$GD^2_{up} = GD^2_M + GD^2_B + GD^2_{Lup} = \boxed{\qquad} + \boxed{\qquad} + \boxed{\qquad}$

$= \boxed{\qquad}$ [kgf•m^2]

Total GD^2_{dn} converted into the equivalent value at the motor shaft during lowering is:

$GD^2_{dn} = GD^2_M + GD^2_B + GD^2_{Ldn} = \boxed{\qquad} + \boxed{\qquad} + \boxed{\qquad}$

$= \boxed{\qquad}$ [kgf•m^2]

2.3 Temporary selection of inverter capacity

(1) Rated torque (T_M) of the temporarily selected motor (60Hz rating basis)

$T_M = \dfrac{974 \times P_M}{N_M} = \boxed{\dfrac{\qquad\qquad}{\qquad\qquad}} = \boxed{\qquad}$ [kgf•m]

(2) Temporary selection of the inverter capacity

According to the motor capacity, select the $\boxed{\text{FR-}\qquad}$.

(3) Determination of the torque type

According to the motor and inverter temporarily selected, the torque type is $\boxed{\qquad}$ with reference to Technical Note No. 22.

Maximum starting torque coefficient $\alpha_s = \boxed{\qquad}$

Linear acceleration torque coefficient $\alpha_a = \boxed{\qquad}$

Heat coefficient $\sigma = \boxed{\qquad}$

(4) Operating frequency range of the temporarily selected inverter

According to $f = \dfrac{(\text{motor speed} \times \text{number of motor poles})}{120}$

Frequency corresponding to the maximum speed

$f_{max} = \dfrac{N_{max} \times P}{120} = \boxed{\dfrac{\qquad\qquad}{\qquad\qquad}} = \boxed{\qquad}$ [Hz]

Frequency corresponding to the minimum speed

$f_{min} = \dfrac{N_{min} \times P}{120} = \boxed{\dfrac{\qquad\qquad}{\qquad\qquad}} = \boxed{\qquad}$ [Hz]

2.4 Whether the Motor Can Be Started and Run at Low Speed or Not

(1) Motor starting torque (T_{MS}) = $T_M \times \alpha_s \times \sigma$ = =
(For α_s and σ, refer to Technical Note No. 22.)

(2) Supposing that load torque at start (T_{LS}) = maximum load torque (T_{Lmax})

Analysis of whether the motor can be started or not

T_{LS} = < T_{MS} =

OK
NG

(3) When the inverter is made one rank higher and examination is made again:

- Torque type
- Maximum starting torque coefficient α_S =
- Linear acceleration torque coefficient α_a =
- Heat coefficient σ =

$T_{MS} = T_M \times \alpha_S \times \sigma$ = =

Analysis of whether the motor can be started or not

T_{LS} = < T_{MS} =

OK
NG

(4) Short-time maximum torque at f_{min} (6Hz or more)

$T_{M1} = T_M \times \alpha_m \times \sigma$ = = [kgf•m]
(For α_m and σ, refer to Technical Note No. 22.)

Analysis of whether low-speed operation can be performed or not

T_{LS} = < T_{M1} =
T_{LS} = < T_{MS} =

OK
NG

2.5 Whether Acceleration/Deceleration is Possible or Not

(1) Acceleration torque during lifting (T_{a1})

$$= \frac{(GD^2_{Lup} + GD^2_{M} + GD^2_{B}) \times N_{max}}{375 \times t_a} = \boxed{\frac{\qquad\qquad}{\qquad\qquad}} = \boxed{\qquad} \text{ [kgf•m]}$$

(2) Deceleration torque during lifting (T_{d1})

$$= \frac{(GD^2_{Lup} + GD^2_{M} + GD^2_{B}) \times N_{max}}{375 \times t_d} = \boxed{\frac{\qquad\qquad}{\qquad\qquad}} = \boxed{\qquad} \text{ [kgf•m]}$$

(3) Acceleration torque during lowering (T_{a2})

$$= \frac{(GD^2_{Ldn} + GD^2_{M} + GD^2_{B}) \times N_{max}}{375 \times t_a} = \boxed{\frac{\qquad\qquad}{\qquad\qquad}} = \boxed{\qquad} \text{ [kgf•m]}$$

(4) Deceleration torque during lowering (T_{d2})

$$= \frac{(GD^2_{Ldn} + GD^2_{M} + GD^2_{B}) \times N_{max}}{375 \times t_d} = \boxed{\frac{\qquad\qquad}{\qquad\qquad}} = \boxed{\qquad} \text{ [kgf•m]}$$

(5) Torque applied to the motor in each region

	Region	Torque applied to the motor [kgf•m]
Lifting	1)	$T_{aup} = T_{a1} + T_{LU} = \boxed{\qquad} = \boxed{\qquad}$
	2)	$T_{LU} = \boxed{\qquad}$
	3)	$T_{dup} = -T_{d1} + T_{LU} = \boxed{\qquad} = \boxed{\qquad}$
	4)	$T_{LU} = \boxed{\qquad}$
Lowering	5)	$T_{adn} = T_{a2} + T_{LD} = \boxed{\qquad} = \boxed{\qquad}$
	6)	$T_{LD} = \boxed{\qquad}$
	7)	$T_{ddn} = -T_{a2} + T_{LD} = \boxed{\qquad} = \boxed{\qquad}$
	8)	$T_{LD} = \boxed{\qquad}$

(6) Torque required for acceleration and deceleration

(a) Torque coefficient required for acceleration during lifting (α)

$$= \frac{Ta_{max}}{T_M} = \frac{\boxed{}}{\boxed{}} = \boxed{}$$

Ta_{max} is either of Ta_{up} in region 1 and Ta_{dn} in region 5, which is larger.
Note that regenerative acceleration is made when $Ta_{up} > 0$ and $Ta_{dn} > 0$. In this case, the maximum torque required for regenerative acceleration is judged by whether deceleration is possible or not. Hence, the judgment of whether acceleration is possible or not is not needed here.

Analysis of whether acceleration is possible or not

$\alpha_a \times \sigma = \boxed{} \times \boxed{} > \alpha = \boxed{}$

OK
NG

α_a: Linear acceleration torque coefficient
σ: Heat coefficient (refer to Technical Note No. 22.)

(b) Torque coefficient required for deceleration during lowering (β)

$$= \frac{|Td_{max}|}{T_M} = \frac{\boxed{}}{\boxed{}} = \boxed{}$$

Td_{max} is either of Td_{up} in region 3 and Td_{dn} in region 7, which is smaller.
Note that driving deceleration is made when $Td_{up} < 0$ and $Td_{dn} < 0$. In this case, the maximum torque required for driving deceleration is judged by whether acceleration is possible or not. Hence, the judgment of whether deceleration is possible or not is not needed here.

(c) Temporary selection of the brake unit

The torque type of the ☐ is ☐ .

<Refer to the braking capability data in Technical Note No. 22.>

Analysis of whether deceleration is possible or not

$\beta_{min} = \boxed{} > \beta = \boxed{}$

OK
NG

β_{min}: Brake torque coefficient (minimum value)

2.6 Examination of Thermal Capacity of the Brake Unit

(1) Operation pattern

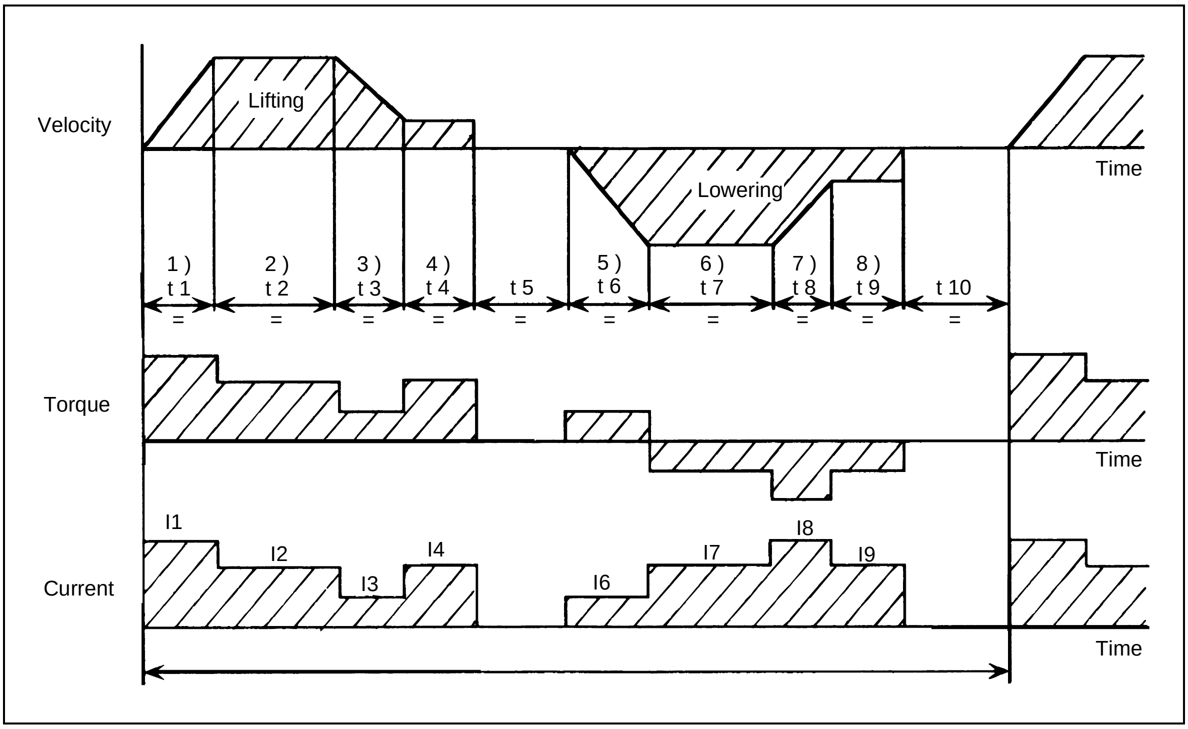

Fig. App.4 Example of Operation Pattern

(2) Formulae for calculating torque and regenerative power in each operation zone

Zone	Regenerative Power [W]
1)	$W_1 = 0.1027 \times \frac{N_1}{2} \times T_{aup} = \boxed{\qquad\qquad} = \boxed{\qquad\qquad}$
2)	$W_2 = 0.1027 \times N_1 \times T_{LU} = \boxed{\qquad\qquad} = \boxed{\qquad\qquad}$
3)	$W_3 = 0.1027 \times \frac{N_1 + N_2}{2} \times T_{dup} = \boxed{\qquad\qquad} = \boxed{\qquad\qquad}$
4)	$W_4 = 0.1027 \times N_2 \times T_{LU} = \boxed{\qquad\qquad} = \boxed{\qquad\qquad}$
5)	$W_6 = 0.1027 \times \frac{N_1}{2} \times T_{adn} = \boxed{\qquad\qquad} = \boxed{\qquad\qquad}$
6)	$W_7 = 0.1027 \times N_1 \times T_{LD} = \boxed{\qquad\qquad} = \boxed{\qquad\qquad}$
7)	$W_8 = 0.1027 \times \frac{N_1 + N_2}{2} \times T_{ddn} = \boxed{\qquad\qquad} = \boxed{\qquad\qquad}$
8)	$W_9 = 0.1027 \times N_2 \times T_{LD} = \boxed{\qquad\qquad} = \boxed{\qquad\qquad}$

(3) Calculation of power

- Power returned from the load [W_{MECH}]

$$W_{MECH} = \frac{|\Sigma(W_n \times t_n)|}{\Sigma t_n}$$

From zones 1) to 8), calculate W_n and t_n only in the zones where power is negative.

= = [W]

- Power returned to the inverter

$W_{INV} = W_{MECH} \times 0.9 =$ = [W]

(4) Short-time permissible power per operation of the braking unit $W_{RS} =$ [W]
(For W_{RS}, refer to Technical Note No. 22.)

Analysis of short-time permissible power

$W_{INV} =$ $< W_{RS} =$

OK
NG

(5) Checking the continuous average regenerative power

$$W_{INV} \times \frac{t_1 + t_2 + \Lambda + t_n}{t_c} = \times = \text{[W]}$$

(t_1 to t_n is the sum total of times when power is negative in operation zones 1) to 8))

(6) Continuous permissible power W_{RC} (refer to Technical Note No. 22) = [W]

Analysis of continuous permissible power

$W_{INV} \times \frac{t}{t_c} =$ $< W_{RC} =$

OK
NG

(7) Checking the short-time permissible power in the continuous regenerative operation zone

$W_n \times 0.9 =$ $< W_{RS}$ (for seconds) =
(For W_{RS} for seconds, refer to Technical Note No. 22.)

2.7 Examination of Whether the Motor Can Be Used Thermally

(1) Required motor torque, load torque factor and current characteristic (%)

	Zone	Torque Supplied to the Load	Load Torque Factor [%]	Current Characteristic [%]	Cooling Coefficient
During rising	t_1	$T_{aup} = T_{a1} + T_{LU}$ =	TF =	I1 =	C1 =
	t_2	T_{LU} =		I2 =	C2 =
	t_4		TF =	I4 =	C4 =
	t_3	$T_{dup} = -T_{d1} + T_{LU}$ =	TF =	I3 =	C3 =
During falling	t_6	$T_{adn} = T_{a2} + T_{LD}$ =	TF =	I6 =	C6 =
	t_7	T_{LD} =		I7 =	C7 =
	t_9		TF =	I9 =	C9 =
	t_8	$T_{ddn} = -T_{d2} + T_{LD}$ =	TF =	I8 =	C8 =

Note: Motor torque used is the above calculated value.

(2) Motor equivalent current value (I_{MC})

$$I_{MC} = \sqrt{\frac{I_1^2 \times t_1 + I_2^2 \times t_2 \ldots\ldots + I_n^2 \times t_n}{C_1 \times t_1 + C_2 \times t_2 + \ldots + C_n \times t_n}}$$

$$= \sqrt{\frac{\qquad}{\qquad}}$$

$$= \sqrt{\frac{\qquad}{\qquad}} = \frac{\qquad}{\qquad} = \boxed{\qquad\qquad} < 100\%$$

2.8 Examination of Stopping Accuracy

(1) Characteristics of the brake

According to Technical Note No. 22, the characteristics of the mechanical brake $\boxed{\qquad\qquad\qquad}$ are:

- Rated braking torque : $T_B = \boxed{\qquad\qquad}$ [kgf•m]
- Delay time (independent off) : $t_{01} = \boxed{\qquad\qquad}$ [s]
- Brake GD^2 : $GD^2_B = \boxed{\qquad\qquad}$ [kgf•m^2]

(2) Stopping accuracy when the motor is running at a slow speed (creep speed), and is brought to a stop

Stopping time (t_b) $= t_{01} + t_{11}$

$$= t_{01} + \frac{(GD_L^2 + GD_M^2 + GD_B^2) \times N_{min}}{375 \times (T_B + T_L)}$$

$$= \boxed{\qquad\qquad} + \boxed{\frac{\qquad\qquad\qquad\qquad}{\qquad}}$$

$$= \boxed{\qquad\qquad} + \boxed{\qquad\qquad}$$

$$= \boxed{\qquad\qquad} \text{ [s]}$$

where,
T_L : Load torque during lifting (T_{LU})
: Load torque during lowering (T_{LD})

Stopping distance (S) $= S_{01} + S_{11} = (t_{01} \times \frac{V_{min}}{60} + t_{11} \times \frac{V_{min}}{60} \times \frac{1}{2}) \times 10^3$

$$= (\boxed{\qquad\qquad} + \boxed{\qquad\qquad\qquad}) \times 10^3$$

$$= \boxed{\qquad\qquad} \text{ [mm]}$$

Guideline of stopping accuracy ($\Delta\varepsilon$) = ±S/2 = $\boxed{\qquad /2}$ = ± $\boxed{\qquad\qquad}$ [mm]

2.9 Determination of the Models

According to the above examination results, the recommended models are as follows:

Motor : kW P
Inverter : FR-
(Control system:)
Braking unit :