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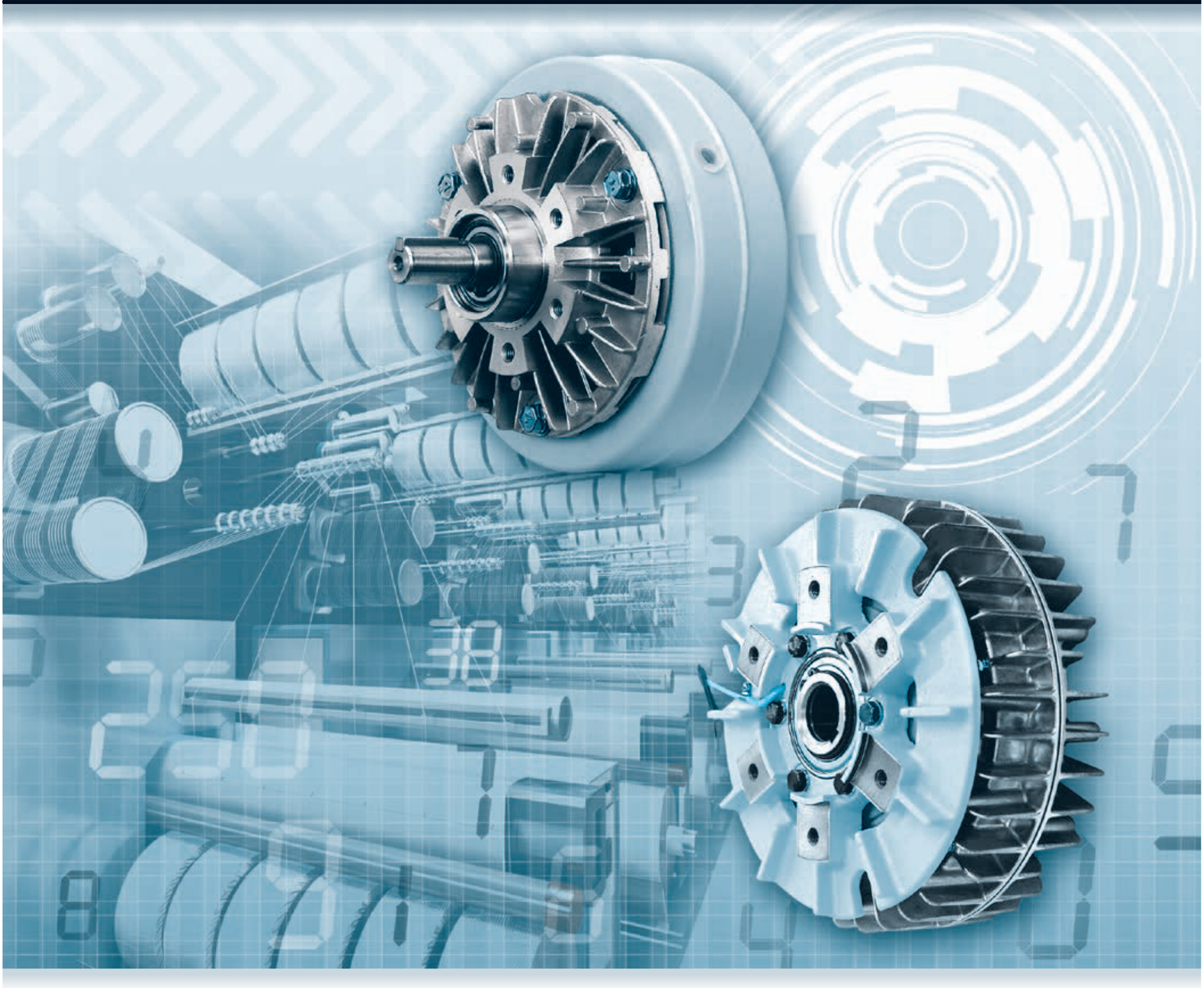
Mitsubishi Electric Electromagnetic Clutches/Brakes

Technical Document



Mitsubishi Electric Electromagnetic Clutches/Brakes

Technical Document

Electromagnetic clutches and brakes are widely used in industrial machinery such as printing machines and paper converting machinery for purposes including tension control and power absorption.
This technical document is designed to provide readers with a deeper understanding of Mitsubishi Electric's lineup of electromagnetic clutches and brakes.

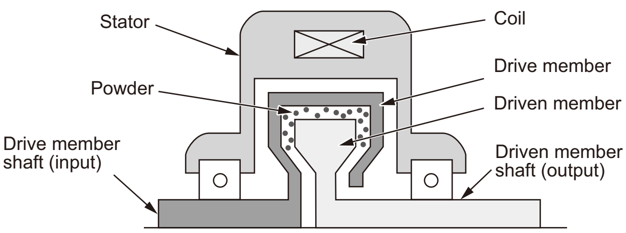
1. Regarding the content of this technical document
   (1) This technical document summarizes the general steps necessary for selection. Please inquire regarding any special information not shown in this technical document.
   (2) For detailed dimensions and specifications, please refer to "MITSUBISHI ELECTRIC ELECTROMAGNETIC CLUTCH/BRAKE TENSION CONTROLLER GENERAL CATALOG."
   (3) Please refer to the instruction manual included with the product for precautions for each model.
2. Regarding SI units
   SI units are used for the units shown in this technical document. Please refer to the conversion table for clutch/brake-related units located at the end of this document.

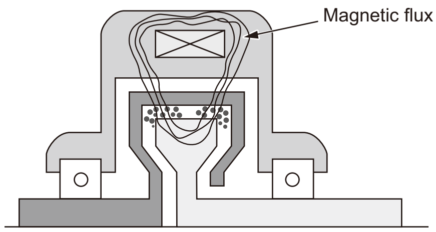
Table of Contents

Mitsubishi Electric Electromagnetic Powder Clutches/Brakes

1. Basic structure and operation

The basic structure of the powder clutch is shown in the figure below. The drive member (input side) and driven member (output side) are placed on a concentric cylinder separated by a powder gap, and both members are supported by bearings so that they can freely rotate.
Powder with high magnetic permeability (magnetic iron powder) is put in the powder gap, and the exciting coil is arranged on the outer circumference so that the magnetic flux flows to it.
While the drive member is rotating without being excited, the powder is pressed against the operating surface of the drive member by centrifugal force, leaving the drive member disengaged from the driven member.
When the coil is excited, powder is connected in a chain along the generated magnetic flux. At this time, torque is transmitted by the coupling force between powders and the frictional force between the powder and the operating surface.
Thus, the powder clutch can also be called a friction clutch using powder as a medium.
In addition, the product in which the driven member (output side) is fixed becomes a powder brake.





When shut down
When current is not passed through the exciting coil, the clutch is released and torque is not transmitted. At this time, powder is pressed against the outer periphery of the powder gap by centrifugal force.

When engaged
When the coil is excited, the magnetic flux connects the powder in a chain inside the powder gap and transmits the torque.

2. Structure of the ZKB series

Models in the static coil ZKB series can be classified depending on the cooling method used.

- ZKB series
  - Natural cooling type
    - ZKB-AN powder clutch
    - ZKB-YN powder brake
  - Natural cooling type & Forced air cooling type
    - ZKB-BN powder clutch
    - ZKB-XN powder brake
  - Thermoblock type
    - ZKB-HBN powder brake

2.1 ZKB-AN powder clutch/ZKB-YN powder brake

Models in the ZKB-AN series of powder clutches and the ZKB-YN series of powder brakes are natural cooling types.

Bearings used

Model name	Bearing
ZKB-0.06AN, -0.06YN	6000
ZKB-0.3AN, -0.3YN	6202
ZKB-0.6AN, -0.6YN	6202

Bearings are special products designed taking such factors as thermal resistance into consideration.

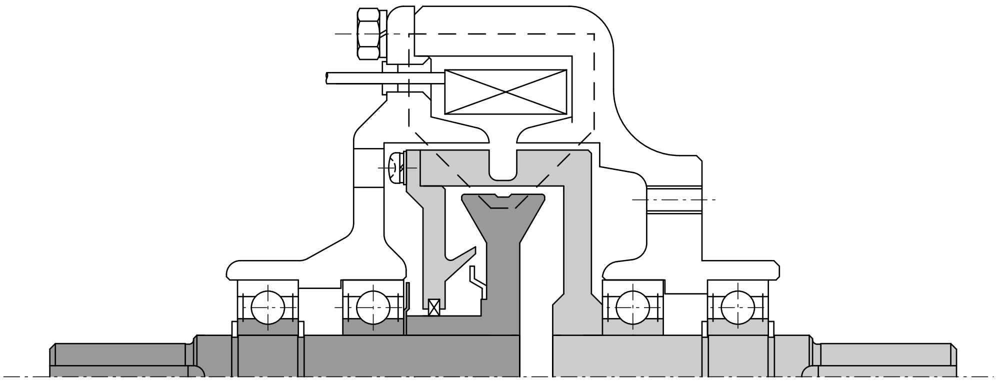


Fig. 1 ZKB-0.06AN to ZKB-0.6AN powder clutches (typical example)

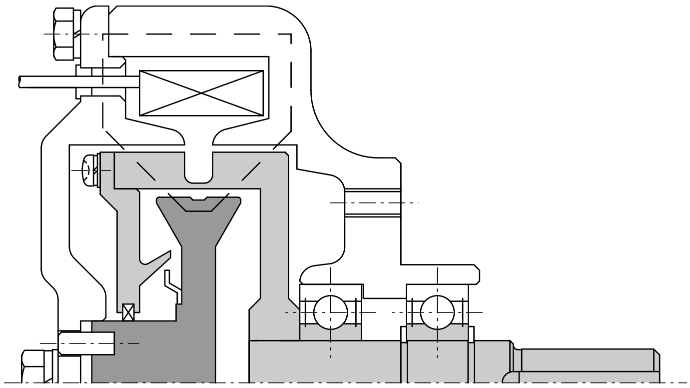


Fig. 2 ZKB-0.06YN to ZKB-0.6YN powder brakes (typical example)

2.2 ZKB-BN powder clutch/ZKB-XN powder brake

Models in the ZKB-BN series of powder clutches and the ZKB-XN series of powder brakes have a structure in which compressed air is blown into the air gap and heat generated by the slip is dissipated to the outside. These models can also be used as natural cooling types. To improve cooling effects when used as natural cooling types, fins are provided on one side of the drive member. Accordingly, the allowable continuous heat dissipation will vary depending on the input rotation speed.

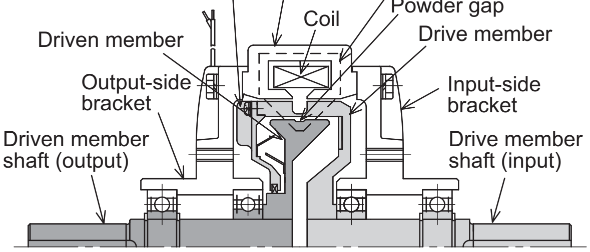


Fig. 3 ZKB-1.2BN to 20BN powder clutches (typical example)

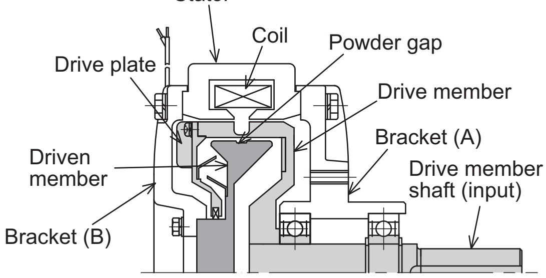


Fig. 4 ZKB-1.2XN to 20XN powder brakes (typical example)

Bearings used

Model name	Bearing
ZKB-1.2BN	6003
ZKB-2.5BN	6005
ZKB-5BN	6206
ZKB-10BN	6307
ZKB-20BN	6308

Bearings are special products designed taking such factors as thermal resistance into consideration.

Bearings used

Model name	Bearing
ZKB-1.2XN	6003
ZKB-2.5XN	6005
ZKB-5XN	6206
ZKB-10XN	6307
ZKB-20XN	6308

Bearings are special products designed taking such factors as thermal resistance into consideration.

2.3 ZKB-HBN powder brake

The ZKB-HBN model powder brake has a thermoblock with excellent thermal conductivity built into the brake and is forcibly cooled by an axial fan.

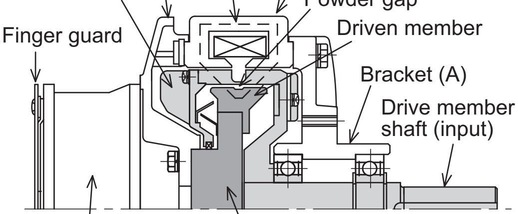


Fig. 5 ZKB-2.5HBN to 20HBN powder brakes (typical example)

Bearings used

Model name	Bearing
ZKB-2.5HBN	6005
ZKB-5HBN	6206
ZKB-10HBN	6307
ZKB-20HBN	6308

Bearings are special products designed taking such factors as thermal resistance into consideration.

3. Structure of the ZKG micro series

The ZKG series features a special structure that reduces the moment of inertia of rotating parts to enable it to withstand high-frequency use.

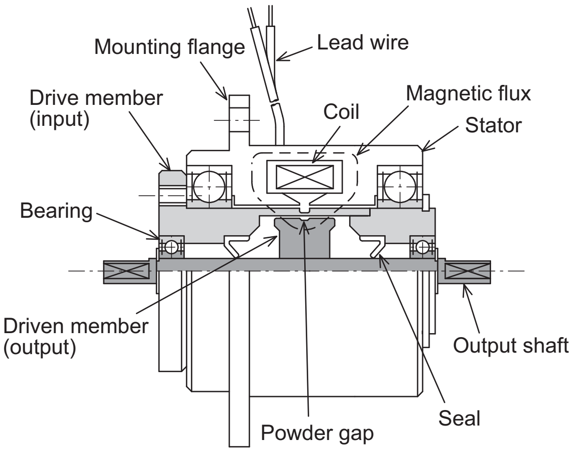


Fig. 1 ZKG-5AN to ZKG-100AN micro powder clutches (typical example)

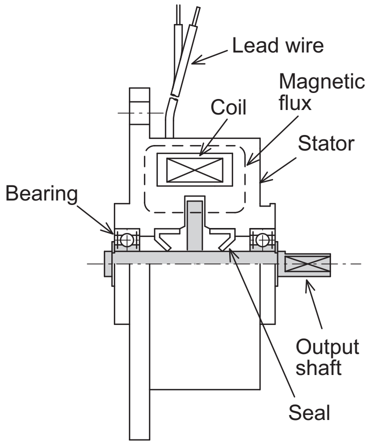


Fig. 2 ZKG-5YN to ZKG-50YN micro powder brakes (typical example)

4. Structure of the ZA series

Static coil, through-shaft models in the ZA series include the ZA-A1 clutch with 6 to 200 N·m and the ZA-Y brake with 6 to 200 N·m. These natural cooling models feature fins and an operating surface for heat dissipation on the outer circumference of input rotation side, enabling extremely high natural cooling effects.

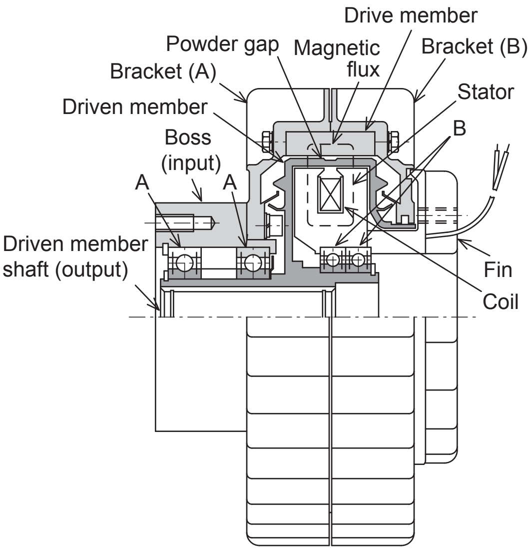


Fig. 1 ZA-0.6A1 to ZA-20A1 powder clutches (typical example)

Bearings used

Model name	Bearing	
	A	B
ZA-0.6A1	6905	6905
ZA-1.2A1	6006	6906
ZA-2.5A1	6006	6907
ZA-5A1	6009	6909
ZA-10A1	6010	6010
ZA-20A1	6014	6014

Bearings are special products designed taking such factors as thermal resistance into consideration.

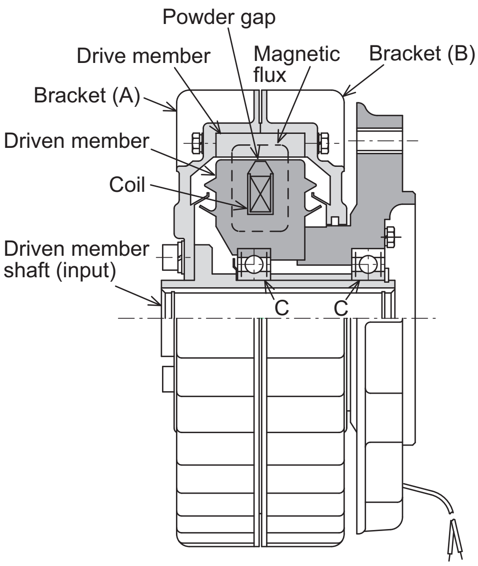


Fig. 2 ZA-0.6Y to ZA-20Y1 powder brakes (typical example)

Bearings used

Model name	Bearing C
ZA-0.6Y	6004
ZA-1.2Y1	6006
ZA-2.5Y1	6006
ZA-5Y1	6009
ZA-10Y1	6010
ZA-20Y1	6014

Bearings are special products designed taking such factors as thermal resistance into consideration.

5. Structure of the ZX series

The ZX series is a thin, through-shaft type that provides excellent cost performance.
The coil used has a rated voltage of 24 V DC.

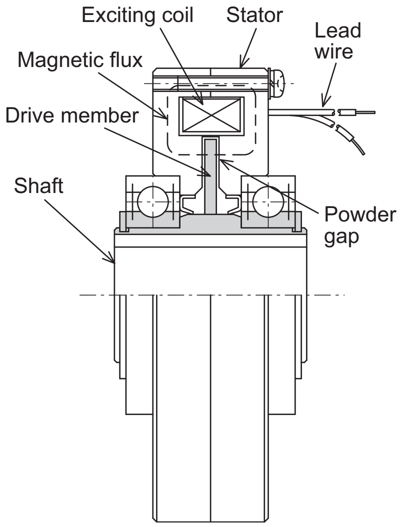


Fig. 1 ZX-0.3YN-24 to ZX-1.2YN-24
powder brakes (typical example)

6. Operation characteristics

This section explains the operation characteristics required when you want to control the startup time or when considering high-frequency repetitive operations. Fig. 1 shows the operations of engaging and releasing the powder clutch. When voltage is applied to the exciting coil, the excitation current rises exponentially with the coil time constant (T = L/R) determined by resistance R and inductance L of the exciting coil. Torque rises very slightly behind the excitation current to the setting torque following the excitation current regardless of the slip rotation speed on the driving side and driven side. The clutch continues to accelerate the load with that torque.
In other words, the clutch can build-up torque to the preset level even if the driving side and driven side are not perfectly engaged. This characteristic is ideal for shockless start/stop and fast start/stop as well as a large clutch heat capacity.
When particularly rapid engagement or braking is required, the build-up of torque can be accelerated by exciting the coil with a high-voltage power supply after reducing the coil time constant by inserting a series resistance in the exciting coil, or by overexciting the voltage 2 or 3 times the rated voltage by the torque time constant. At the rated excitation, the torque builds up perfectly in coil time constant T of 4 or 5T. On the other hand, the time taken for the torque to decay when the excitation is interrupted is approx. 1T.

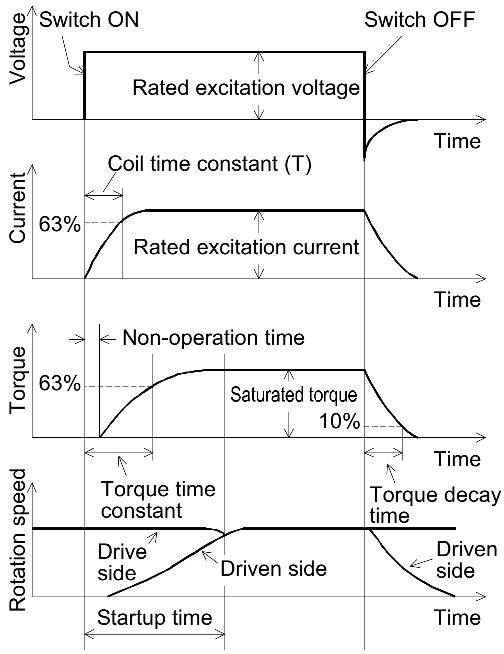


Fig. 1 Operation characteristics of the powder clutch

Tables 1 to 4 show the coil time constant and torque time constant of each series.

Table 1 ZKB series coil time constants and torque time constants

Model name	Coil time constant (s)	Torque time constant (s)
ZKB-0.06AN	0.03	0.09
ZKB-0.3AN	0.08	0.13
ZKB-0.6AN	0.08	0.13
ZKB-1.2BN	0.10	0.18
ZKB-2.5BN	0.12	0.20
ZKB-5BN	0.13	0.27
ZKB-10BN	0.25	0.5
ZKB-20BN	0.35	1.2

Note 1. The time constants of ZKB-XN, YN, and HBN are the same as those in Table 1.

Note 2. The values in the tables are measurement examples of the slip rotation speed of 200 r/min after completion of running in.
If the powder clutch has been left for a long time or the idling time is long, the torque time constant may become larger.
Also note that as the powder deteriorates, the torque time constant increases.

Note 3. The tables show the values at a coil temperature of 75°C.

Table 2 ZA series coil time constants and torque time constants

Model name	Coil time constant (s)	Torque time constant (s)
ZA-0.6A$_1$	0.04	0.08
ZA-1.2A$_1$	0.04	0.10
ZA-2.5A$_1$	0.06	0.13
ZA-5A$_1$	0.09	0.17
ZA-10A$_1$	0.14	0.30
ZA-20A$_1$	0.30	0.90
ZA-0.6Y	0.10	0.20
ZA-1.2Y$_1$	0.13	0.20
ZA-2.5Y$_1$	0.15	0.25
ZA-5Y$_1$	0.17	0.35
ZA-10Y$_1$	0.30	0.70
ZA-20Y$_1$	0.60	1.0

Table 3 ZKG series coil time constants and torque time constants

Model name	Coil time constant (s)	Torque time constant (s)
ZKG-5AN	0.02	0.04
ZKG-10AN	0.03	0.07
ZKG-20AN	0.05	0.10
ZKG-50AN	0.06	0.13
ZKG-100AN	0.09	0.37
ZKG-5YN	0.020	0.04
ZKG-10YN	0.020	0.04
ZKG-20YN	0.034	0.07
ZKG-50YN	0.045	0.09

Table 4 ZX-YN series coil time constants and torque time constants

Model name	Coil time constant (s)	Torque time constant (s)
ZX-0.3YN-24	0.035	0.09
ZX-0.6YN-24	0.05	0.1
ZX-1.2YN-24	0.07	0.15

7. Torque build-up characteristics

If the torque build-up is slow at rated excitation, it can be accelerated by means such as rapid excitation, rapid overexcitation, or overexcitation.
Figs. 1 and 2 show torque build-up characteristics when rapid excitation, rapid overexcitation, and overexcitation are used for the ZKB-5BN model powder clutch.

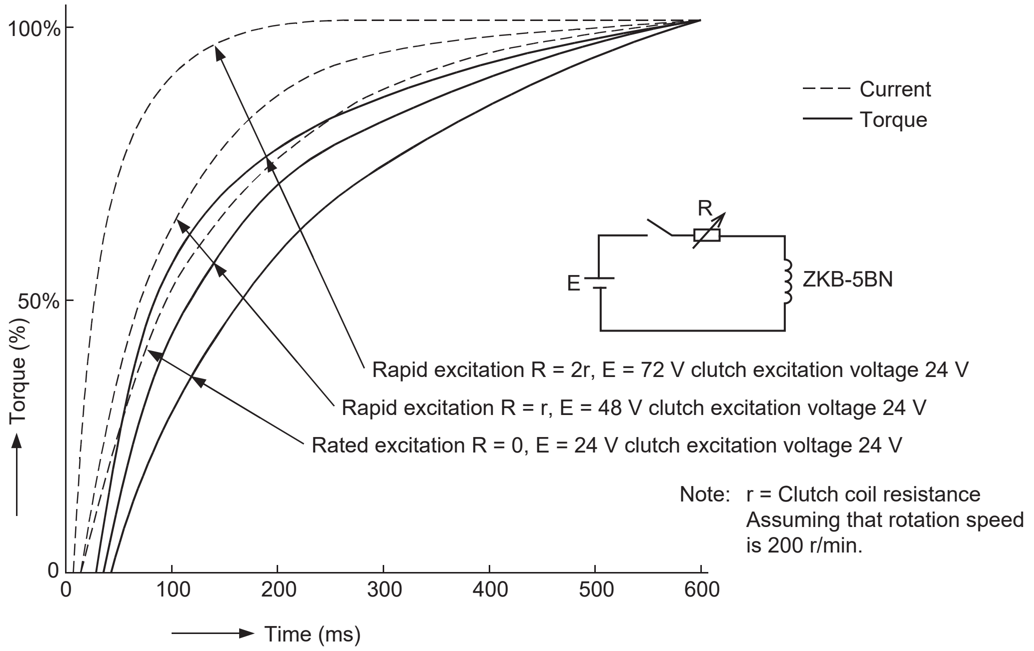
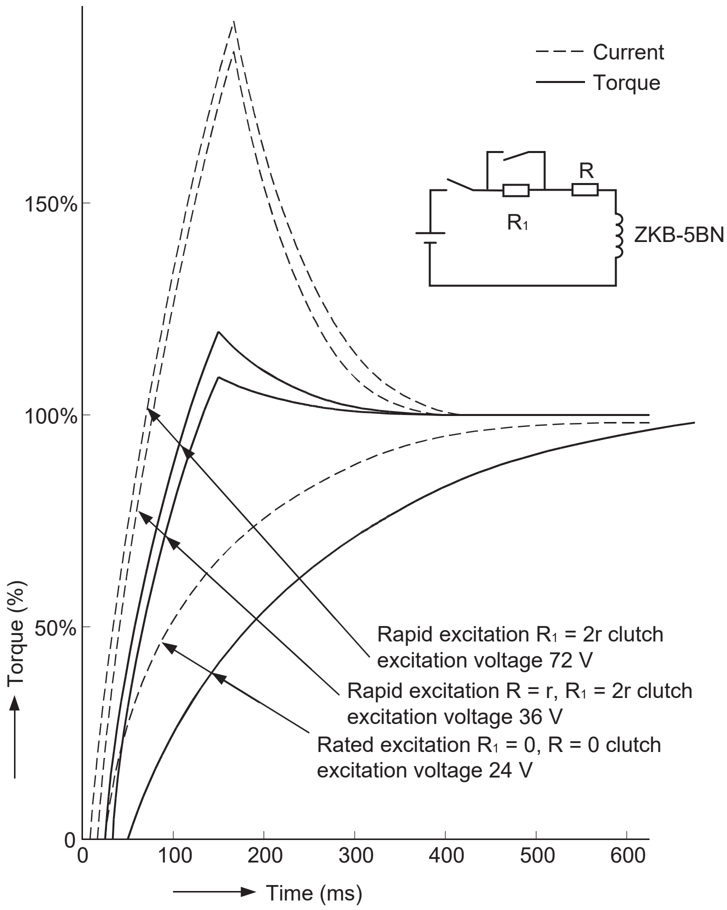


Fig. 1 Torque build-up characteristics when using rapid excitation for the ZKB-5BN powder clutch



Note 1. The overexcitation time is to be approximately 1/2 or less than the torque time constant (see Tables 1 to 4) and the root-mean-square voltage is not to exceed the rated voltage. The root mean square is to follow the following calculation example.
48 V × 0.2 s, 20 V × 3 s, rest × 1 s

$$\text{Root mean square voltage} = \sqrt{\frac{48^2 \times 0.2 + 20^2 \times 3}{0.2 + 3 + 1}}$$

$$\approx 20 \text{ V}$$

Note 2. Figs. 1 and 2 show examples of when there is no load torque.
In the case of start-up engagement, the driven side does not start rotating until the clutch torque becomes larger than the load torque (in this case, the torque that keeps stopping the driven side).

Fig. 2 Torque build-up characteristics when using rapid overexcitation and overexcitation for the ZKB-5BN powder clutch

8. Excitation current vs. torque characteristics

Fig. 1 shows an example of the excitation current vs. torque characteristics of a ZKB series powder clutch.
As is clear from this figure, the torque is proportional to the excitation current over a wide range, indicating good controllability of torque.
The torque is proportional to the current in the range of 5 to 100% of the rated torque.
If used in combination with an automatic control device, even the idling torque of the product can be controlled. Although the idling torque is approximately 2% of the rated torque, this will vary depending on the model. For details, please refer to the catalog.

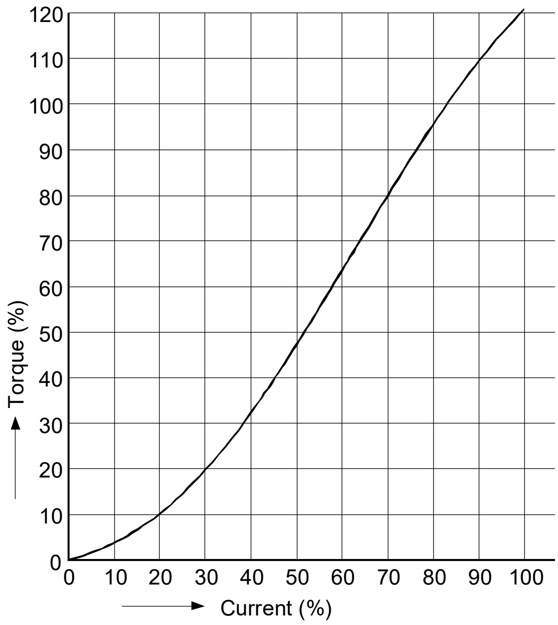
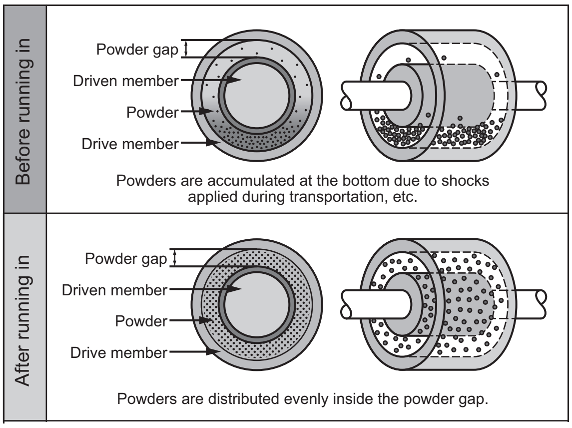


Fig. 1 ZKB series current vs. torque characteristics (typical example)

9. Running in

1. What is running in?
   Since the powder inside the powder clutch/brake is unevenly distributed due to shock during transportation, running in must be performed before starting regular operation.
   To obtain the intrinsic performance of the powder clutch/brake, it is important that the powder is evenly distributed within the powder gap.
   If the powder is unevenly distributed, the torque may decrease, fluctuate, become fixed, etc., preventing the product from demonstrating its intrinsic performance.
   Running in can uniformly distribute the unevenly distributed powder within the powder gap and generate a stable torque proportional to the excitation current.



2. Running in procedure
   This is an example of an effective method of running in if regular running in is difficult.
   Note. In either case, be careful not to cause the surface temperature of the clutch/brake to exceed the limit shown in the instruction manual or catalog.
   [Reference] Regular running in condition
   (1) In the case of a clutch, fix it to prevent the output shaft from rotating.
   (This step is unnecessary when the load torque is large.)
   (2) Rotate the input shaft at approx. 200 r/min for approx. 1 minute. Then while rotating,
   (3) Set the excitation current to 1/4 to 3/4 of the rated value and excite it approx. 10 times in the cycle of ON for 5 seconds and OFF for 10 seconds.
   If the uneven distribution of the powder is large and it is difficult to perform running in, repeat approx. 10 times in the cycle of ON for 5 seconds and OFF for 10 seconds at the rated excitation.

■ When the rotation speed of the input shaft cannot be set to approx. 200 r/min
Set the excitation current ON time as follows.
Calculate the time until the number of revolutions of the input shaft reaches approx. 20 times.
Example: In the case of 30 r/min

$$60 \text{ seconds} \times \frac{1}{30 \text{ r/min}} \times 20 \text{ times} = 40 \text{ seconds}$$

Therefore, turn ON for 40 seconds, turn OFF for 10 seconds, and repeat it approx. 10 times.
In some cases, it may be effective to repeat ON for 2 seconds and OFF for 0.5 second at the rated excitation.

■ When the output shaft cannot be fixed in the case of a clutch
(1) Increase the load to make it as difficult as possible for the output shaft to rotate.
(2) Set the excitation current to approx. 1/8 to 1/4 of the rating.
(3) Set the ON time as follows. Calculate the time until the relative rotation of the input shaft and output shaft reaches approx. 20 times in total.
Example: In the case of input shaft 300 r/min and output shaft 280 r/min
Relative rotation speed 300 - 280 = 20 r/min

$$60 \text{ seconds} \times \frac{1}{20 \text{ r/min}} \times 20 \text{ times} = 60 \text{ seconds}$$

Therefore, turn ON for 60 seconds, turn OFF for 10 seconds, and repeat it approx. 10 times.
Even if the running in is carried out in the above manner, the effect is slightly inferior to the regular case, but the running in will be gradually completed during normal operation.

3. Effect of running in
   Figs. 1 and 2 show torque measurement examples when the excitation current is turned ON and OFF and when it is kept ON.
   When the excitation current is turned ON and OFF, the torque becomes higher every time the current is turned ON and OFF, which verifies the effect of running in.
   On the other hand, if the excitation current remains ON, the figure shows that the torque becomes saturated in the low state.

Rotation speed 50 r/min
Excitation current: 0.93 A
(3/4 of rated current)
ON for 5 seconds/OFF for 10 seconds
Repeating 10 times

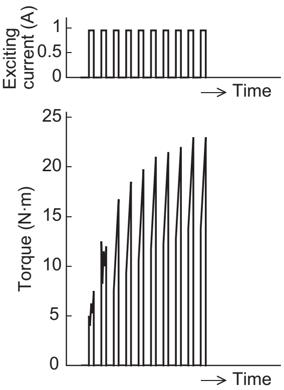


Fig. 1 Measurement example when turning the excitation current ON and OFF
(ZKB-2.5XN powder brake)

Rotation speed 50 r/min
Excitation current: 0.93 A
(3/4 of rated current)
ON for 140 seconds

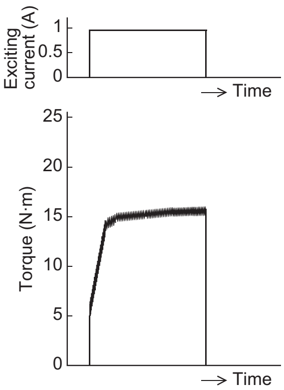


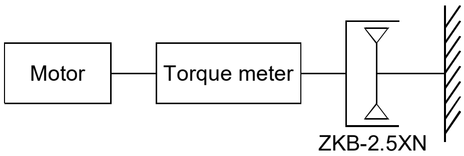
Fig. 2 Measurement example when maintaining the excitation current ON
(ZKB-2.5XN powder brake)

* In the following cases, running in is insufficient.
 (1) Torque output remains low.
 (2) Torque does not stabilize.
 (3) Noise, pulsation of torque, or sticking at startup occurs.

10. Slip rotation speed vs. torque characteristics

Fig. 1 shows a torque measurement example in which the excitation current of the ZKB-2.5XN powder brake is used as a parameter and the brake rotation speed is changed from 0 to 1,000 r/min.
Although the degree of torque stability will vary slightly depending on the model, if the excitation current is kept constant, torque can be kept constant irrespective of the slip rotation speed (the difference in rotation speed between the drive member and driven member). This is because magnetic iron powder, which is also called a semisolid, is used as a medium for power transmission.
In other words, this characteristic means that there is no difference between the static friction torque and dynamic friction torque, indicating the ease of torque control.
This characteristic not only allows continuous slip and increases the heat capacity but also widens the scope of application of powder clutches and brakes such as for tension control, shockless startup, and torque limiting.

Test configuration



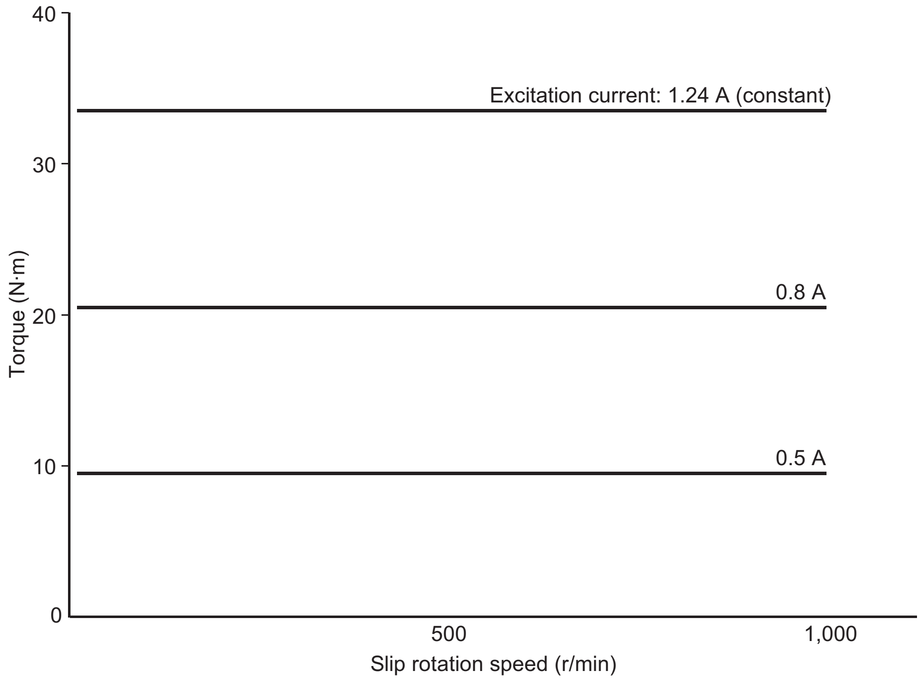


Fig. 1 Slip rotation speed vs. torque characteristics (measurement example)

11. Hysteresis characteristics and idling torque characteristics

As the powder clutch increases and decreases the excitation current, the torque characteristic shows the hysteresis characteristic.
Fig. 1 shows hysteresis characteristics for the excitation current of the ZKB-5BN clutch when 0 A -> 0.75 A -> 0 A, 0 A -> 1.5 A -> 0 A, and 0 A -> 2.15 A -> 0 A. As is clear from this characteristic, the hysteresis width changes depending on the magnitude of the excitation current.
Even if the excitation current is interrupted completely, idling torque is generated due to mechanical losses arising from residual magnetism of the powder, grease of the bearing, and friction such as from the seal. Accordingly, torque control below this idling torque cannot be performed.
Refer to the catalog for idling torque values of each model.

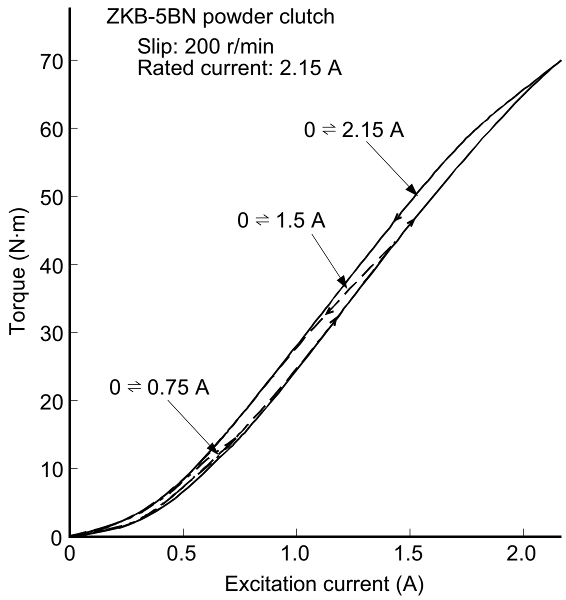


Fig. 1 Torque and hysteresis characteristics of the powder clutch (measurement example)

12. Torque stability

Fig. 1 shows the torque stability when the input rotation speed of the ZKB-10XN brake is set to 700 r/min, the excitation current is set to 0.37 A, and a cycle of 30 minute operation and 15 minute rest is repeated three times.

Fig. 2 also shows the torque stability when the input rotation speed is set to 150 r/min, the excitation current is set to 0.67 A, and cycles are repeated in the same manner.

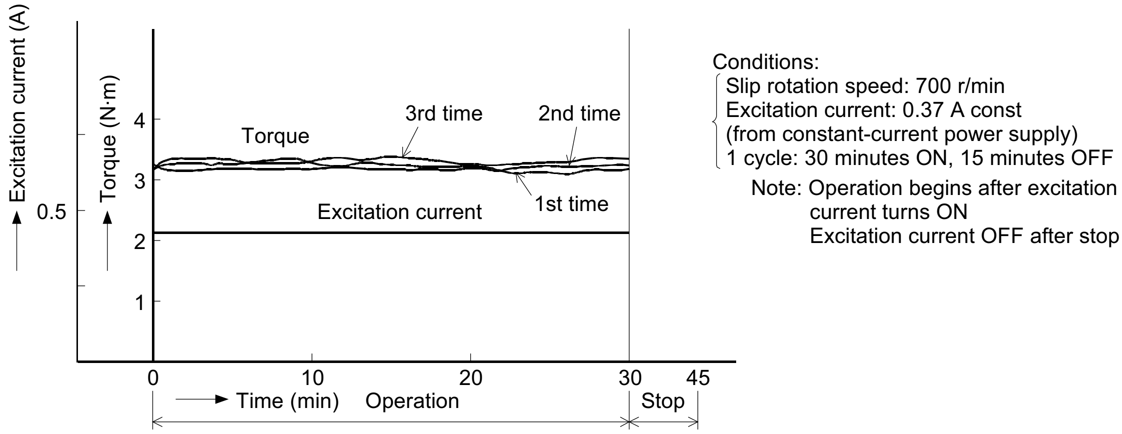


Fig. 1 ZKB-10XN powder brake transmission torque transition (measurement example)

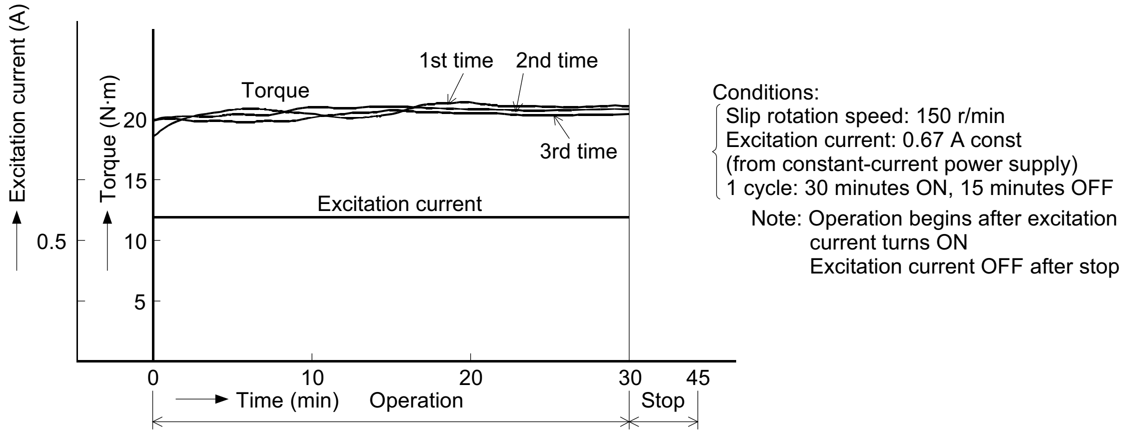


Fig. 2 ZKB-10XN powder brake transmission torque transition (measurement example)

13. Torque reproducibility

Fig. 1 shows a measurement example for torque reproducibility when the input rotation speed of the ZKB-2.5XN powder brake is set to 50 r/min, the excitation current is set to 0.9 A, and a cycle of 10 seconds ON and 2 seconds OFF is repeated 20 times.

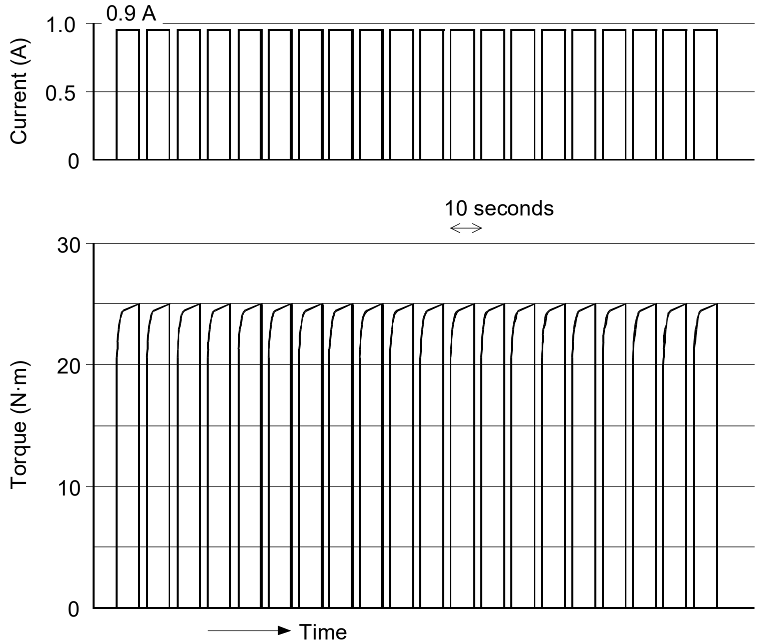
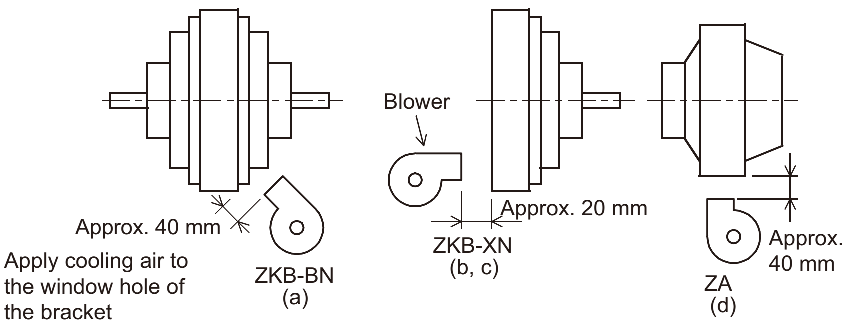


Fig. 1 Torque reproducibility (measurement example)

14. Improving allowable continuous heat dissipation using blower cooling

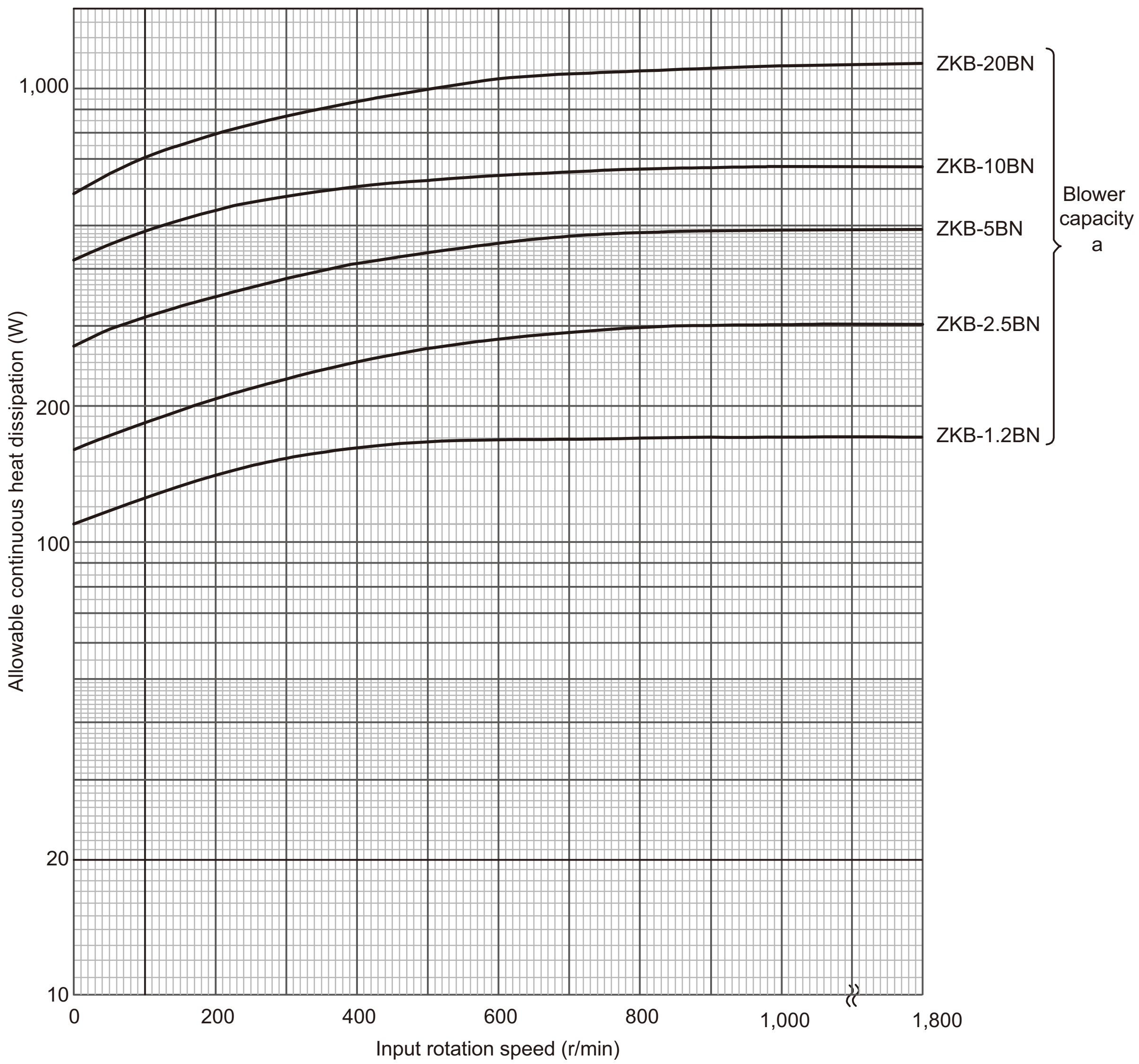
The allowable continuous heat dissipation of the powder clutch/brake can be increased by using a blower. When using blower cooling, the allowable continuous heat dissipation will vary depending on factors such as the capacity and position of the blower and whether or not a duct is used. With the graph in the next section as a guide, use blower cooling to ensure that the surface temperature of the powder clutch/brake is kept at 80°C or lower.

1. Mounting example



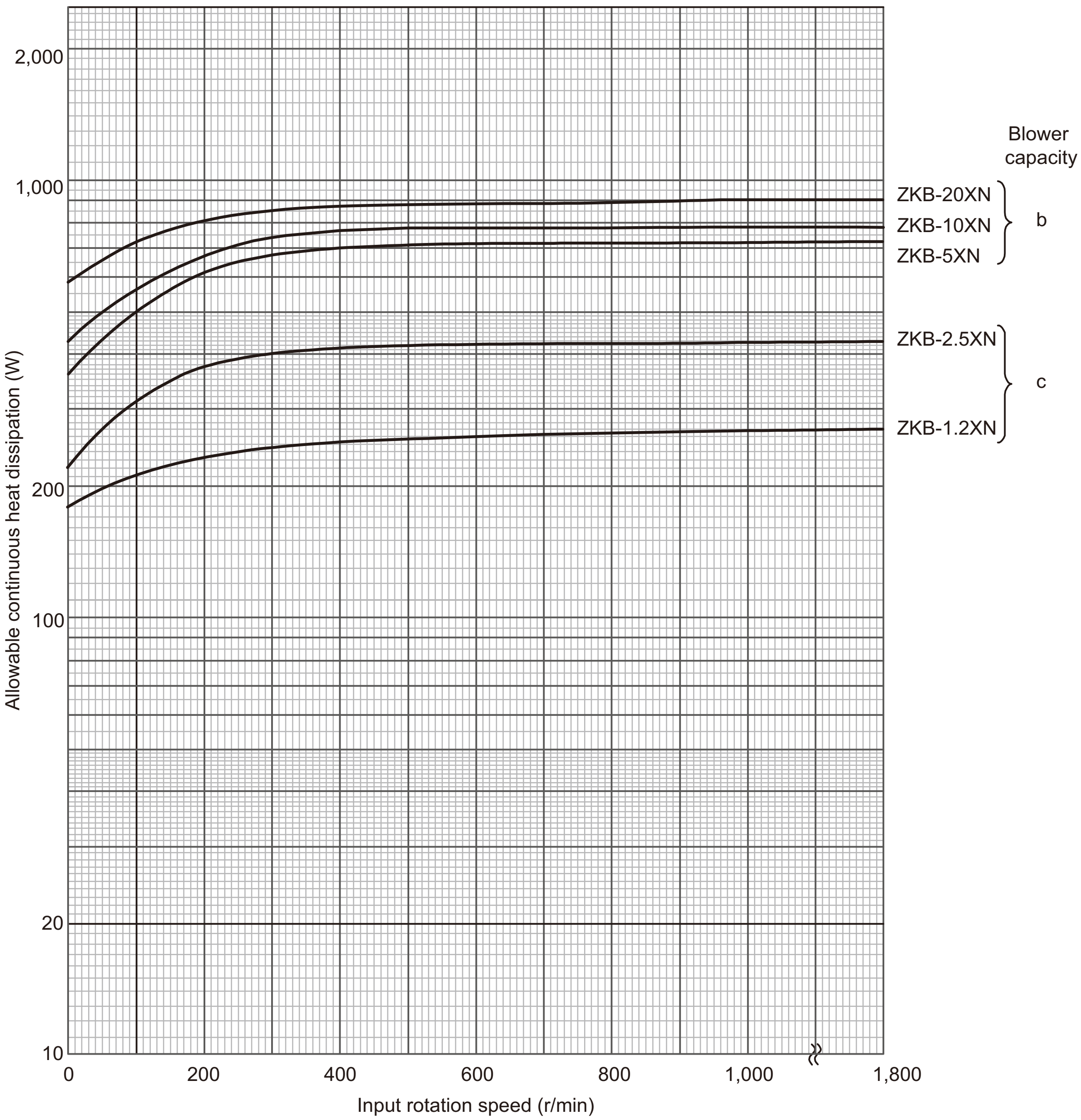
2. Blower capacity

Symbol in graph	Air volume (m^3/min)	Static pressure (Pa)	Applicable blower (manufactured by Mitsubishi Electric)
a	12.3	210	(50 Hz) Single-suction sirocco fan BF-19S_4
			(60 Hz) Single-suction sirocco fan BF-19S_4
b	4.6	200	(50 Hz) Single-suction sirocco fan BF-19S_4
			(60 Hz) Single-suction sirocco fan BF-17S_4
c	1.7	180	(50 Hz) Single-suction sirocco fan BF-17S_4
			(60 Hz) Single-suction sirocco fan BF-16S_4
d	2	100	(50 Hz) Single-suction sirocco fan BF-16S_4
			(60 Hz) Single-suction sirocco fan BF-12S_4



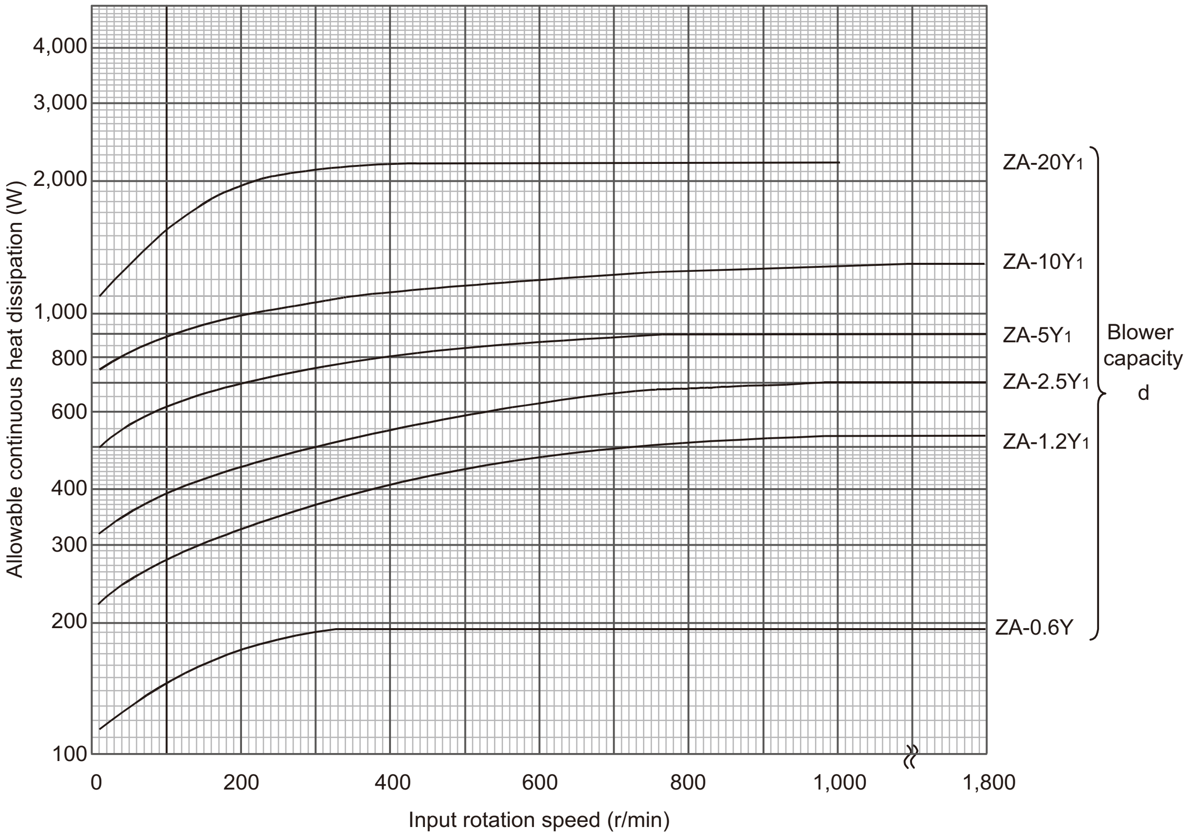
ZKB-BN powder clutch (during blower cooling)

* Refer to page 66 for the allowable continuous heat dissipation when naturally cooled.



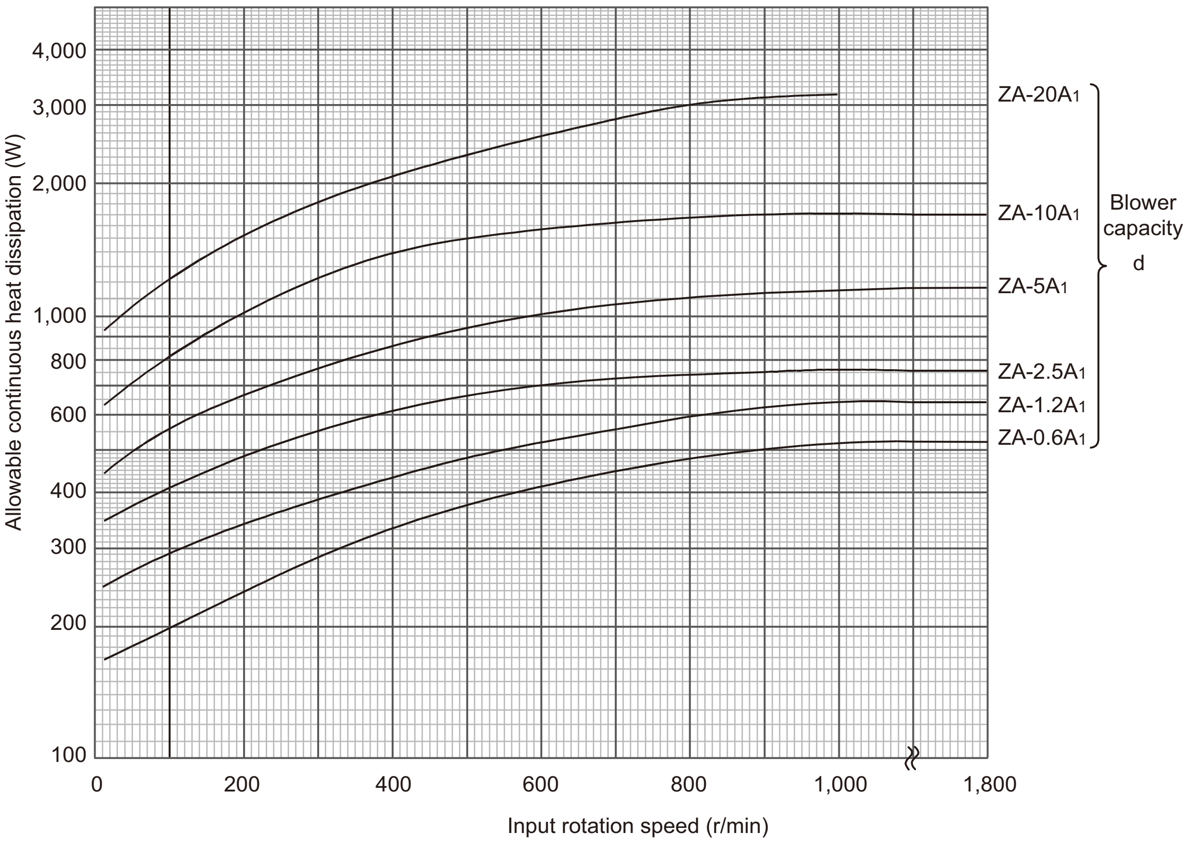
ZKB-XN powder brake (during blower cooling)

* Refer to page 66 for the allowable continuous heat dissipation when naturally cooled.



ZA-Y powder brake (during blower cooling)

* Refer to page 69 for the allowable continuous heat dissipation when naturally cooled.



ZA-A1 powder clutch (during blower cooling)

* Refer to page 68 for the allowable continuous heat dissipation when naturally cooled.

15. Durability

One factor that affects the durability of the powder clutch is the grease in the powder and on the bearings. The allowable engagement energy and allowable continuous heat dissipation are set to values that will not result in powder burning, sintering, or bearing grease deterioration, and that enable the powder clutch to be exposed to those temperatures for a significantly long period of time.
Although powder will oxidize when used for long periods of time and torque characteristics will decrease as a result, considering that the life of the powder clutch spans until torque drops by 30% from its initial value, it will have a lifespan of approx. 5,000 to 8,000* hours when used within the allowable amount of engaging energy and allowable continuous heat dissipation. Needless to say, if used at levels below allowable values, it can be expected to have an even longer lifespan.
For example, in one case, the ZKB-5BN was used for tension control at 20% of the rated torque and at 70 to 80% of the allowable continuous heat dissipation (natural cooling). After five years, its torque had only decreased 10 to 20%. Many such cases exist.
On the other hand, be aware that the powder will oxidize rapidly if used in circumstances where allowable values are exceeded, which may in turn accelerate torque deterioration and result in damage to parts.
We will now discuss the results of bench durability tests.

* These are estimated values when used for general winding and unwinding.

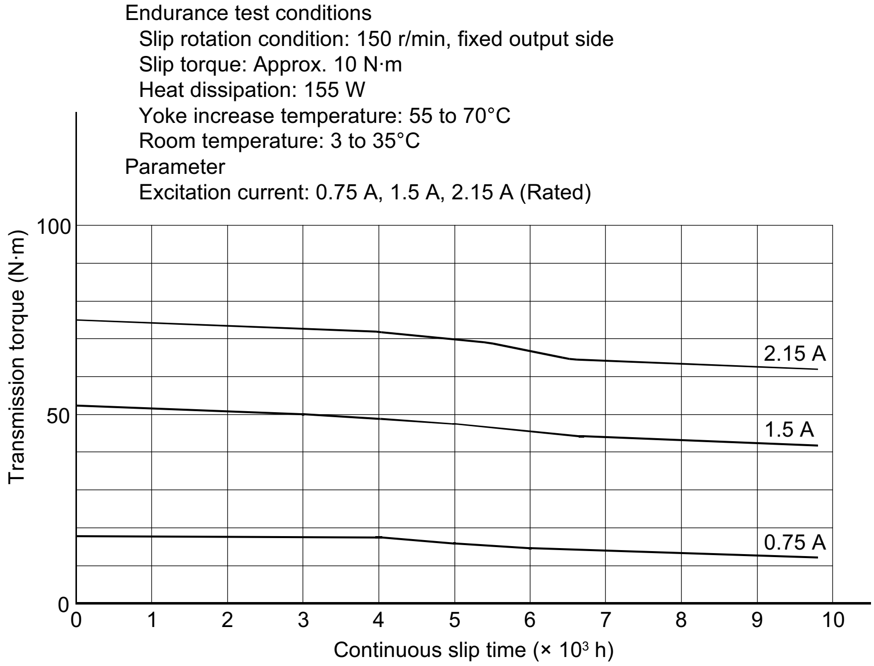


Fig. 1 Torque characteristic transition during ZKB-5BN durability test (measurement example)

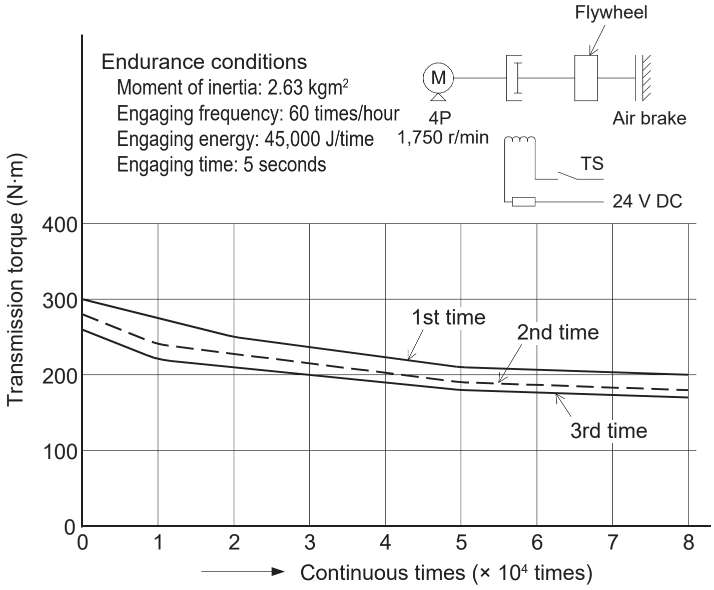


Fig. 2 Torque characteristic transition during ZKB-20BN durability test (measurement example)

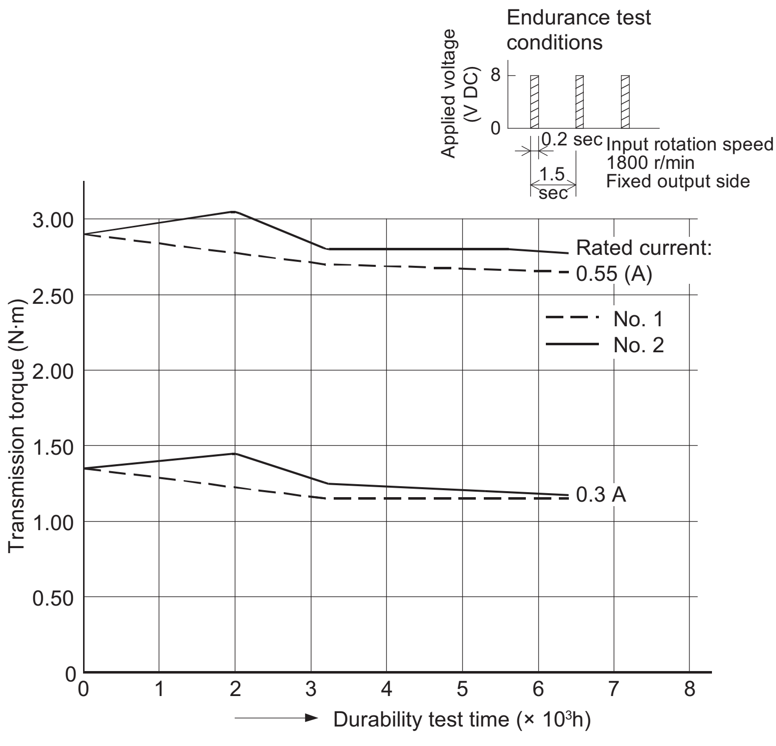


Fig. 3 Torque characteristic transition during ZKG-20AN durability test (measurement example)

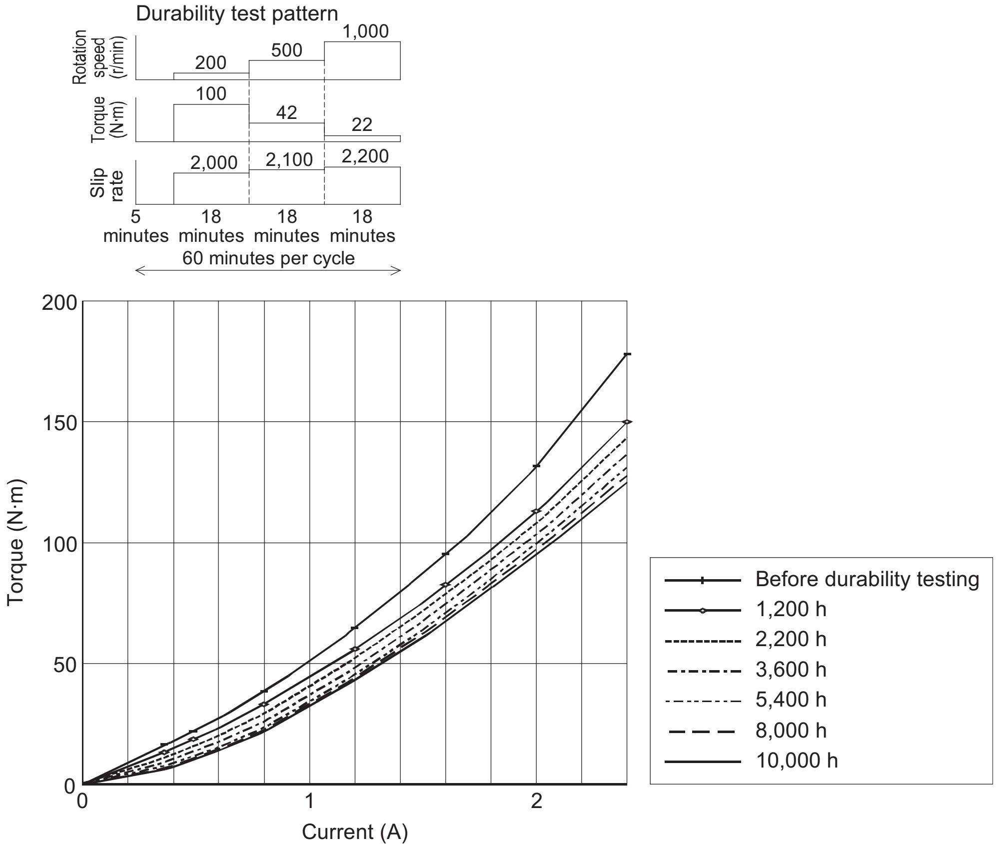


Fig. 4 Result for current vs. torque characteristics from ZKB-10HBN powder brake durability test (measurement example)

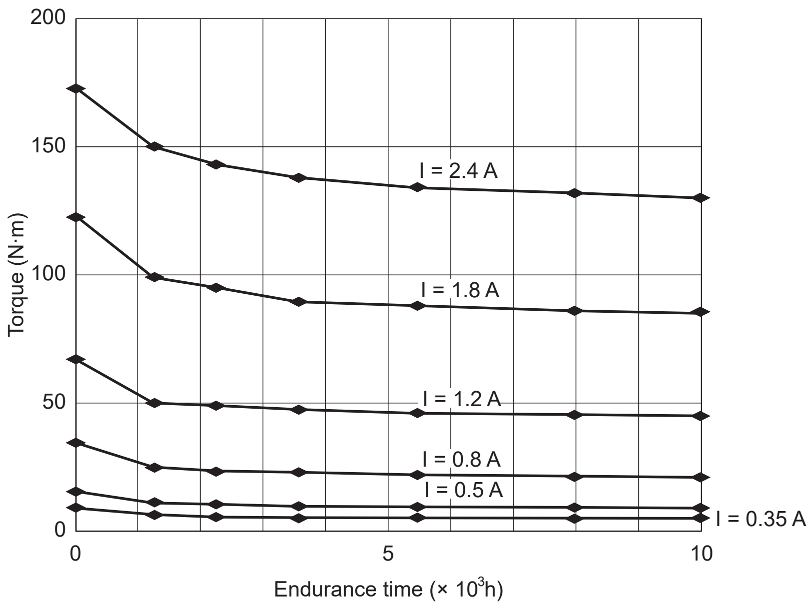


Fig. 5 Torque transition during ZKB-10HBN powder brake durability test (measurement example)

Figs. 4 and 5 show an example for the ZKB-10HBN powder brake when used in tension control mode. Although torque decreases are seen between 1,000 to 2,000 hours, decreases become more gradual after that. According to this data, torque is still 130% of the rated torque even after 10,000 hours, meaning that it can still be used for much longer.

16. Allowable shaft load

If a pulley or the like is used when engaging the input and output of the powder clutch/brake, torque is transmitted to apply a radial load F perpendicular to the shaft. Because bearings are used inside the powder clutch/brake, the size of this radial load F must be limited in consideration of bearing fatigue life. (Hereinafter, the allowable value for this radial load is referred to as the "allowable shaft load.")

Radial load F is calculated using the following equation.

$$F = \frac{2T}{D} \times K \quad (N)$$

T: Transmission torque (N·m)
D: Pulley diameter (m)
K: Load factor
(timing belt 1.5, V belt 2.5, sprocket 1.5)

The formula for calculating the basic rated lifespan of bearings is as follows:

$$L_h = 500 \times \frac{33.3}{n} \times \left(\frac{C}{F_0}\right)^3 \quad (h) \text{..........................(1)}$$

L_h: Basic rated lifespan of bearing (reliability: 90%) (h)
C: Basic dynamic rated load (N)
n: Rotation speed (r/min)
F_0: Radial load applied to bearing (N)

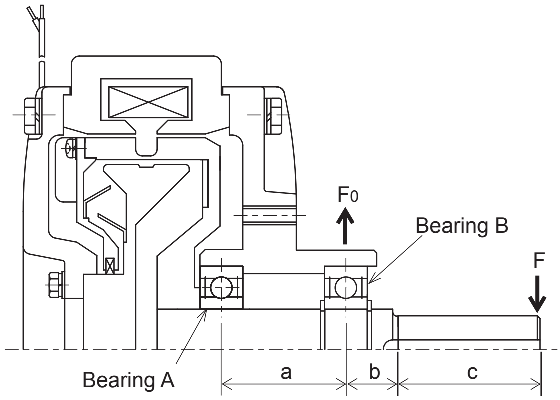
As an example, we will perform a calculation for the ZKB powder clutch/brake. As seen in the figure, the ZKB powder clutch/brake has two bearings, A and B (same for input shaft and output shaft), which support the shaft. When a load F is applied to the end of the shaft, the load F_0 applied to bearing B is as follows:

$$F_0 = F \times \frac{a + b + c}{a} \quad (N) \text{....................................(2)}$$

From equations (1) and (2), the allowable shaft load *F* for the shaft end is as follows:

$$F = \frac{a}{a + b + c} \times \frac{C}{\sqrt[3]{\frac{L_h \times n}{500 \times 33.3}}} \quad (N) \text{..................(3)}$$

If the load position is not the shaft end, calculate by changing the length of "c" in equations (2) and (3).



The allowable shaft load for each model is shown.

Points to be noted for all models

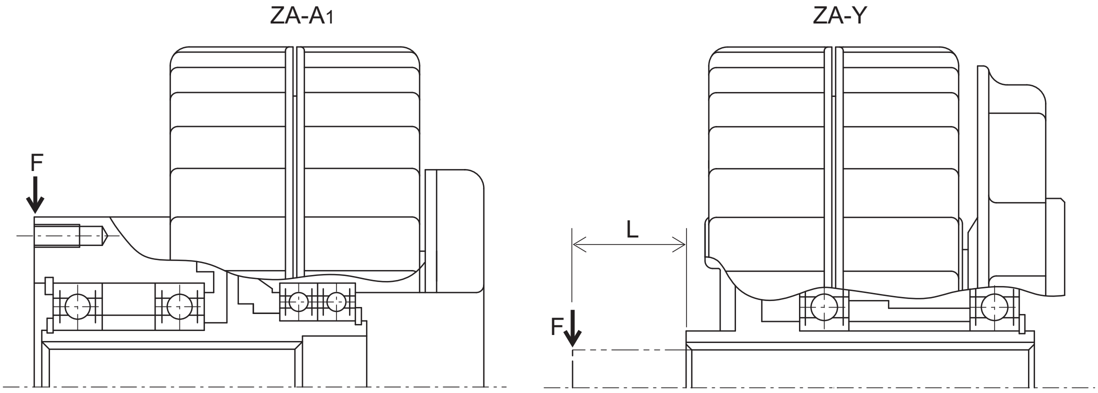
(1) Allowable shaft load represents the smaller value of the shaft strength and the allowable radial load for the bearing.
(2) Bearing load is based on a lifespan of 15,000 hours.
(3) Thrust loads cannot be received in principle.

16.1 ZKB series

Model name	Bearing size	Basic dynamic rated load C (N)	Dimension in axial direction (mm)			Allowable shaft load F (N)			
			a (mm)	b (mm)	c (mm)	300 (r/min)	500 (r/min)	1,000 (r/min)	1,800 (r/min)
ZKB-0.06	#6000	4,550	14.5	10	22	140	140	125	120
ZKB-0.3	#6202	7,650	19.5	11.5	22	280	280	245	240
ZKB-0.6	#6202	7,650	19.5	13.5	26	330	330	260	215
ZKB-1.2	#6003	6,000	30	13	29	360	325	255	210
ZKB-2.5	#6005	10,100	31.5	14	44	550	460	365	300
ZKB-5	#6206	19,500	45	16.5	56	975	975	770	635
ZKB-10	#6307	33,500	58	20.5	65	2,090	1,760	1,400	1,150
ZKB-20	#6308	40,500	67	25.5	69	2,600	2,190	1,740	1,430

Since both shafts of each ZKB powder clutch have the same configuration, the allowable shaft loads of both the input side and the output side are the same.
Also, even if a cooling method other than either natural cooling or forced air cooling is used, a clutch and brake with the same torque size will have the same allowable shaft load.
The load point is based on the shaft end face.

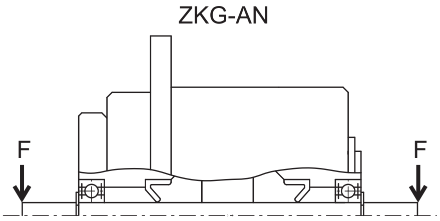
16.2 ZA series

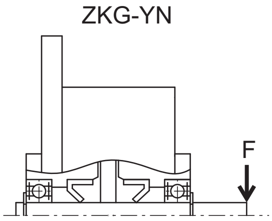


Model name	Dimension L (mm)	Allowable shaft load F (N)			
		300 (r/min)	500 (r/min)	1,000 (r/min)	1,800 (r/min)
ZA-0.6A1	-	560	470	375	310
ZA-1.2A1	-	1,080	910	720	590
ZA-2.5A1	-	1,120	950	750	620
ZA-5A1	-	1,790	1,510	1,190	980
ZA-10A1	-	1,930	1,630	1,290	1,060
ZA-20A1	-	4,430	3,740	2,960	-
ZA-0.6Y	28	305	260	205	170
ZA-1.2Y1	32	340	290	230	185
ZA-2.5Y1	44.5	425	360	285	235
ZA-5Y1	58	880	760	600	500

The load application point is based on the position indicated by “F” in the figure.
Note that when the load application point is outside the “F” position, the allowable value becomes smaller.
In principle, pulleys cannot be directly applied to ZA-10Y1 and ZA-20Y1.

16.3 ZKG series

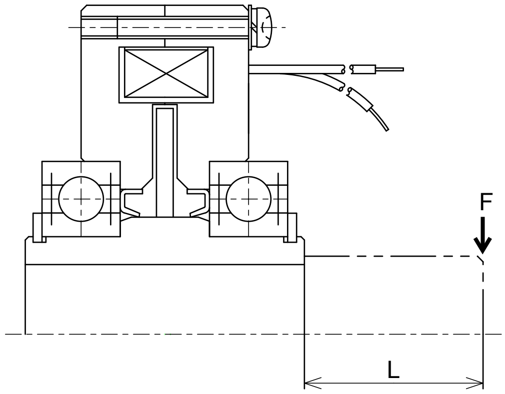




Model name	Allowable shaft load F (N)			
	300 (r/min)	500 (r/min)	1,000 (r/min)	1,800 (r/min)
ZKG-5AN	30	30	30	30
ZKG-10AN	75	75	75	75
ZKG-20AN	120	120	120	120
ZKG-50AN	210	210	210	210
ZKG-100AN	240	240	240	240
ZKG-5YN	30	30	30	30
ZKG-10YN	75	75	75	75
ZKG-20YN	120	120	120	120
ZKG-50YN	450	400	340	280

Since both shafts of each ZKG powder clutch have the same configuration, the allowable shaft loads are the same.
The load point is based on the shaft end face.
Note that when the load application point is outside the shaft end face, the allowable value becomes smaller.

16.4 ZX series



Model name	L (mm)	Allowable shaft load F (N)		
		100 (r/min)	200 (r/min)	400 (r/min)
ZX-0.3YN-24	24	1,000	795	630
ZX-0.6YN-24	28	1,305	1,035	820
ZX-1.2YN-24	32	1,485	1,180	935

The load application point is based on the position indicated by “F” in the figure.
Note that when the load application point is outside the “F” position, the allowable value becomes smaller.

17. Using the powder brake for revolving operations

When the powder brake unit revolves and centrifugal force is applied, such as when used for a stranding machine, the centrifugal force will affect torque characteristics. Thus, the following points are to be considered when used for such applications.

17.1 Installation method

Although Figs. 1 and 2 show two conceivable methods for attaching a powder brake to a stranding machine, the method shown in Fig. 2 cannot be used because centrifugal force in the axial direction is applied to the powder brake.

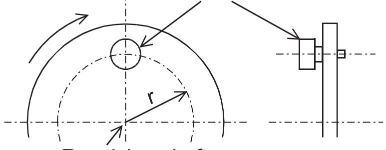


Fig. 1

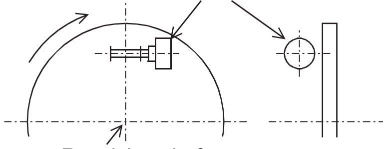


Fig. 2

17.2 Allowable centrifugal force

Although the method shown in Fig. 1 can be used, centrifugal force in the axial direction must be limited in consideration of bracket strength, etc. The allowable centrifugal force of each model is as follows. Ensure that centrifugal force is less than the allowable centrifugal force.

1. ZKG-5 to 50YN

Allowable centrifugal force: 27 (G)

2. ZKB-0.06 to 0.6YN

Allowable centrifugal force: 60 (G)

3. ZKB-1.2 to 5XN

Model name	Allowable centrifugal force (G)
ZKB-1.2XN	25
ZKB-2.5XN	15
ZKB-5XN	12

4. ZA-0.6Y to 5Y1

Model name	Allowable centrifugal force (G)
ZA-0.6Y	20
ZA-1.2Y1, 2.5Y1, 5Y1	15

In addition, when centrifugal force is applied, allowable shaft load is also limited as shown below.

$$F2 \leq \frac{F}{G}$$

$$G = \frac{r\omega^2}{9.8} = \frac{r}{9.8} \times \left(\frac{2\pi n}{60}\right)^2$$

F2: Allowable shaft load (N) when revolving
F: Normal allowable shaft load (N)*
G: Centrifugal force (G)
ω: Angular velocity (rad)
r: Revolution radius (m)
n: Rotation speed (r/min)

* Refer to pages 25 to 27 for information on normal allowable shaft load F.

17.3 Other precautions

1. Performance

If centrifugal force is applied while the excitation is off, powder will be unevenly distributed and it will not be possible to obtain the intrinsic torque performance.

2. Mounting bolts

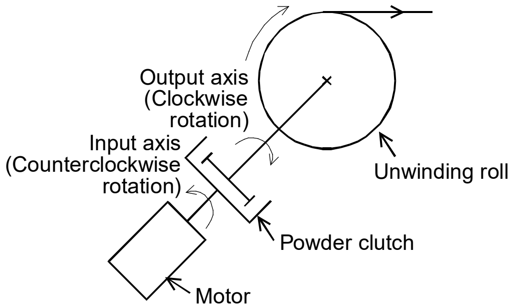
As a general rule, the bolts used to mount the brake unit to the machine are to have a strength equivalent to JIS standard strength classification 8.8 or higher (products made from S45C steel such as hexagon socket head cap bolts).

18. Usage at low rotation speeds

Using the powder brake at low rotation speeds causes the distribution of the powder inside the brake to become uneven, preventing its intrinsic performance from being obtained. Normally, usage at a rotation speed of 15 r/min or more (approx. 5 r/min for ZKB, ZKG, and ZX) is recommended. However, if usage at a low rotation speed is unavoidable due to the machine configuration, performance can be improved by considering the following points.
In the case of a powder clutch, even if the rotation speed of the output side engaged to the winding reel is low, there is no particular problem as long as the rotation speed of the input side is set so that the slip rotation speed (difference between the slip rotation speeds of the input and output) is sufficient.

1. Using the powder clutch for reverse input

The output side (or input side) of the powder clutch is engaged to the unwinding reel, a device such as a geared motor is connected to the input side (or output side), and the unwinding wheel is always rotated in the direction opposite to the rotation direction. This ensures a sufficient slip rotation speed and enables stable torque control.
As for the mounting directions of the input and output sides of the clutch, the input side of the clutch is usually engaged with the side with the higher rotation speed.
In other words, if the line speed is slow and the rotation speed of the unwinding reel is always low, the input side of the clutch is to be engaged with the motor.
On the other hand, if the diameter at the start of unwinding is large and rotation is only temporarily slowed at the start of unwinding, the output side is to be engaged with the motor for most operating hours providing a sufficient slip rotation speed can be obtained.



2. Weak excitation current

Performing weak excitation (energized with an excitation current of approx. 5 to 10% of the rated current) even when idling or when the machine is stopped enables the powder on the inside to be held on the operating surface, the torque build-up time at restart to be shortened, and torque control to be stable. Excitation with a higher current is also possible as long as it does not interfere with machine operation.

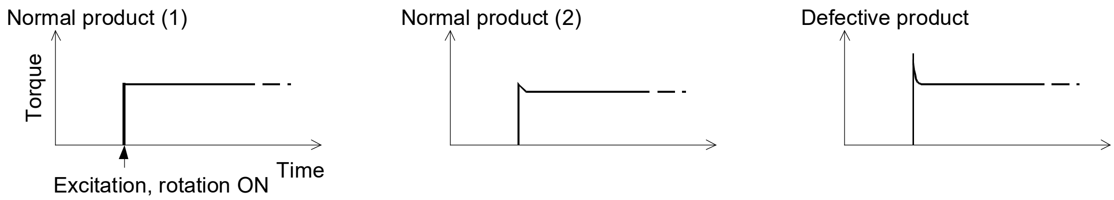
3. Coupling selection

A low elastic coupling such as a chain coupling is to be used for the elastic coupling used for connecting to the load shaft.
(Using a highly elastic type such as a rubber coupling will cause torque to be transmitted intermittently and will result in torque unevenness.)
Also, increase the rigidity of each part of the machine.

19. Abnormal torque at startup

19.1 Phenomenon

A torque exceeding the set value (sticking at startup) may be generated at the moment the powder clutch or brake starts to slip at the start of winding or unwinding.



19.2 Causes and countermeasures

		Cause	Countermeasure
1	Powder unevenness	If clutch excitation is turned on with the powder unevenly distributed inside the clutch, the powder will solidify while unevenly distributed. If rotated in that state, the powder will become twisted, causing torque higher than the set value to be generated. Although this value is normally only a few percent or less of the set torque, it may increase if the powder is moist due to water or oil, etc., or if the powder is distributed unevenly.	(1) Set a time lag so that excitation turns on a few seconds after the clutch starts rotating. (2) Always perform weak excitation at approx. 5 to 10% of the rated current, even when the clutch is stopped and idling.
2	Residual magnetism during sudden stops	When the brake is used to stop the machine suddenly, rotation stops with the powder tightly packed on the operating surface of the brake. If started in that state, brake torque from the time of sudden stopping will remain, possibly causing high torque to be generated momentarily.	Set a time lag so that excitation turns on a few seconds after the brake starts rotating.
3	Drive member heat shrinkage	This occurs when the drive member that has thermally expanded during operation at high load shrinks during cooling and bites the powder with the driven member (powder gap). A phenomenon may occur in which, after operation is stopped, the shaft does not rotate the next morning.	(1) Allow the shaft to idle several times immediately after operation is stopped. (2) In the event the shaft does not turn, apply a light impact to the coupling attached to the shaft using a lead hammer.

<Common items>

Also check the following items.

(1) Was running in performed sufficiently?

(2) Is the rotation speed too low?

(3) Is machine vibration excessive, etc.?

(4) Is oil from the gearbox, etc., getting into the clutch/brake?

20. Noise from the powder clutch/brake

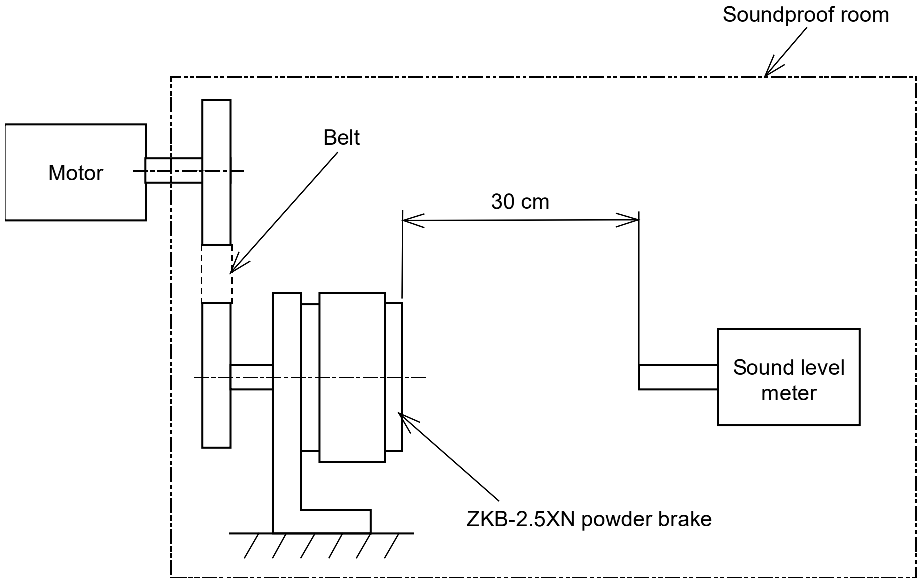
The powder clutch/brake does not generate engagement noise or braking noise, unlike friction plate type clutches/brakes. However, it generates friction noise due to electromagnetic force because the powder clutch/brake are also of a friction type that uses powder as a medium.
Although this friction noise is at a level that does not cause problems for normal machines, caution is necessary when quietness is required, such as when measuring motor noise.

[Noise measurement example for the ZKB-2.5XN powder brake]

<Measurement conditions>

Rotation speed: 50 r/min
Electric current: 0.96 A (equivalent to 25 N·m of rated torque)
Measurement distance: 30 cm
Background noise: 33.7 dB
Noise A characteristics

<Configuration>



<Measurement results>

With excitation current	50.3 dB
Without excitation current	36.4 dB

Note. The above data is a measurement example.
Noise levels may increase due to powder distribution inside the product and matching with other machines.

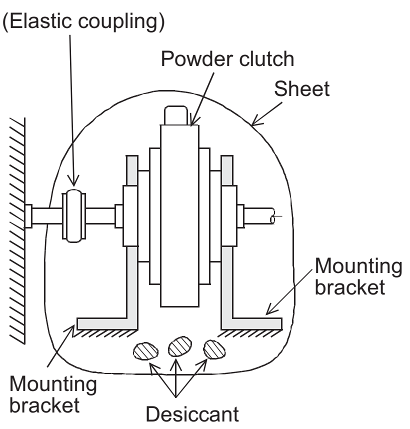
21. Packaging procedure at the time of export

If the powder clutch is mounted to a machine to be exported and is transported through hot and humid areas such as tropical climates, take measures to prevent moisture by referring to the examples below.

1. Packaging procedure

Sheet: Polyethylene film 0.15T
Desiccant:

- Products with a rated torque of 12 N·m or less
  One 300 g bag of silica gel
- Products with a rated torque of 25 to 200 N·m
  Five 300 g bags of silica gel



(a) As shown in the figure above, use two polyethylene sheets to completely seal the powder clutch part.

(b) Place the desiccant (silica gel) inside.

(c) Cover the sheet with a net, etc., to prevent it from tearing.

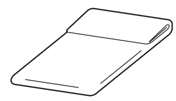
The above does not apply if the entire machine to be packaged for export by being vacuum-packed.

2. When transporting only the powder

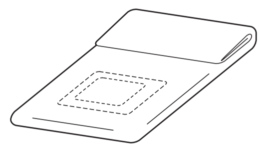
When transporting only the powder, take countermeasures by referring to the following.

(1) Procedure

(a) Place the powder in a plastic bag and seal it.



(b) Then, place the powder that was sealed in the bag above in another polyethylene bag together with the desiccant and seal the bag.



(c) After performing the above, store the plastic bag in a suitable container to prevent it from tearing.

3. Required amount of desiccant

Powder	Desiccant
Up to 50 g	100 g
50 to 300 g	200 g
300 to 500 g	300 g
More than 500 g	Add 300 g for every 500 g of powder

4. Precautions

(1) Use silica gel or an equivalent as the desiccant.

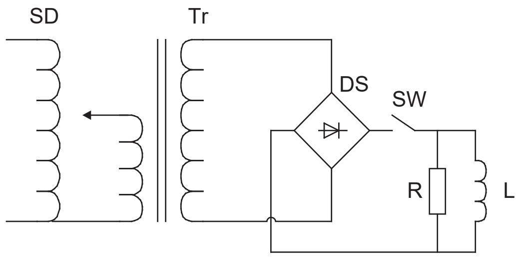
(2) Replace the desiccant every 3 months.

(3) Use a plastic bag with a thickness of 0.15 mm or more.

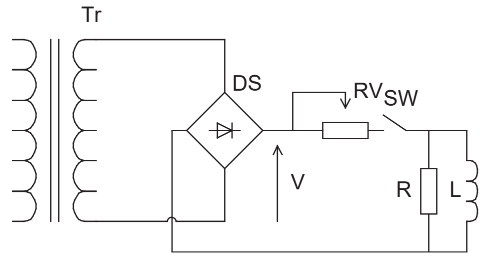
(4) Fold up the plastic bag so it has as small of a surface area as possible.

22. Example of torque adjustment circuit

The following types of simple power supplies can be used for applications in which there is no need to change the torque once it has been set, such as when using a clutch as an engagement device.



(a) Variable transformer method



(b) Series resistance method

Symbol legend

- DS: Diode stack
- SD: Variable transformer
- Tr: Transformer
- SW: Switch
- L: Load (electromagnetic clutch/brake)
- R: Protective resistor
- RV: Variable resistor
- V: Voltage regulator output voltage

Selection

When the clutch/brake has a rated voltage of 24 V DC and is to be used with continuous energization, selection is to be performed using the following criteria.

1. Rectifier/ammeter
Select a rectifier and ammeter suitable for a current that is 1.1x (1.3x) that of the rated current when the clutch/brake is 20°C (75°C).
If using multiple clutches/brakes simultaneously, make a selection based on the combined current thereof.

2. Transformer
Select a transformer with a capacity (VA) that is 1.3x (1.5x) the rated excitation current (W) when the clutch/brake is 20°C (75°C).
If using multiple clutches/brakes simultaneously, make a selection based on the combined current thereof.

3. Variable transformer
Select a variable transformer with a capacity that is 1.1x that of the required capacity of the transformer.

4. Variable resistor
Resistance: Select using the following formula as a guideline.

(RV)

$$RV = R\left(\frac{V}{V_R} \times \frac{1.3T_R}{T_{min}} - 1\right)$$

R:	Resistance when the clutch/brake is 75°C
V_R:	Rated voltage of clutch/brake
T_R:	Rated torque of clutch/brake
T_{min}:	Minimum usage torque
V:	Voltage regulator output voltage
Rated power:	Select a variable resistor with a rated power that is 0.7x (1x) the product of the square of the rated current when the clutch/brake is 20°C (75°C) and the total resistance (RV) of the variable resistor.

5. Protective resistor

Resistance (R): Select a protective resistor with a resistance that is approx. 15x (13x) the resistance of the clutch/brake at 20°C (75°C).

Rated power: Select a protective resistor with a rated power equivalent to the reciprocal of the resistance (R) multiplied by 2,500.

$$\cdots\cdots \quad \frac{1}{R} \times 2{,}500$$

23. Varistor selection

Surge voltage will occur between terminals when the excitation of the clutch/brake is interrupted. Varistors have a property in which their resistance drops sharply when a voltage higher than the specified value is applied. By utilizing this property, surge voltage is converted into heat by the varistor and consumed to protect the circuit.

[Calculation for varistor selection]

$Vp = V \times 1.414$

$P = \frac{1}{2} \times L \times I^2$

- Vp: Peak voltage (V)
- P: Energy withstand capacity (J)
- V: Coil voltage (V)
- L: Coil inductance (H)
- I: Excitation current (A)

(Calculation example)

For ZKB-5BN

V = 24 (V)

I = 2.15 (A)

L = 3.5 (H)

Vp = 24 × 1.414 = 33.9 (V)

$P = \frac{1}{2} \times 3.5 \times 2.15^2 = 8.1$ (J)

Based on the above, select a varistor with a varistor voltage of 33.9 V or higher and an energy withstand capacity of 8.1 (J) or higher (calculation example: Z10D121).

A simple selection can also be made using Table 1.

Table 1 Simple varistor selection table
(manufacturer: SEMITEC Corporation)

Excitation current	Varistor	Varistor voltage (V)	Energy withstand capacity (J)
1 A or less	Z5D121	120 (108 to 132)	3.5
2 A or less	Z7D121		7.0
3 A or less	Z10D121		14.5
4 A or less	Z15D121		30.0

Note 1. The above assumes the clutch/brake is turned on/off 10 times per minute. In case of higher frequencies, select a large-capacity varistor to provide a margin.
(Contact the manufacturer for details.)

Note 2. This table does not guarantee functionality. Perform sufficient confirmation tests when using.

24. Selection procedure for powder clutches/brakes

24.1 Overview

When selecting a powder clutch/brake, it is necessary to calculate the torque, rotation speed, and heat dissipation (heat generation) to be used, and confirm that all are within the allowable range.
Selection methods and points to be noted are explained below for each of these items.

1. Torque

The maximum and minimum values for the torque to be used must be calculated and confirmed to be within the controllable range. The torque control range of powder clutches/brakes ranges from the rated torque to the idling torque* of the product (2 to 100% of the rated torque).
(*Idling torque: Due to the loss torque of the bearings and seals inside the product, the torque will not be 0 N·m even if the excitation current is 0 A. Although the idling torque is normally approx. 2% of the rated torque, it will vary by product. Confirm using the catalog when making an actual selection.)

2. Rotation speed

The maximum rotation speed must be less than or equal to the allowable rotation speed for both the powder clutch and brake. In the case of a powder brake, the minimum rotation speed must be 15 r/min or more, and in the case of a powder clutch, the difference in rotation speed between the input and output must be 15 r/min or more. (In other words, both the powder clutch and powder brake require a slip rotation speed of 15 r/min or more.)
If the slip rotation speed is low, the distribution of the internal powder will be poor, preventing stable torque performance from being obtained or resulting a long time being necessary to reach the specified torque at startup.
ZKB, ZKG, and ZX powder clutches/brakes can be used from a slip rotation speed of approx. 5 r/min.

3. Heat dissipation (heat generation)

The amount of heat generated per unit time due to powder clutch/brake slips is called “heat dissipation.” Because the powder clutch/brake is normally used in a continuous slip state, the temperature of the powder clutch/brake unit is increased by the slip heat. This temperature rise is limited by the thermal resistant temperature of the parts used, with the allowable continuous heat dissipation (allowable value for heat dissipation) being specified for each model. Thus, the powder clutch/brake can be used under stable conditions for long periods of time if operated under conditions below this allowable value. On the contrary, if the powder clutch/brake is used beyond this allowable continuous heat dissipation, the powder clutch/brake will fail in an extremely short period of time. For this reason, ensure that the heat dissipation does not exceed the allowable continuous heat dissipation across the entire ranges for rotation speed and torque during its usage.

Heat dissipation (heat generation) P (W) is calculated using the following equation.

$P = 0.105 \times T \times Nr$ (W)

T: Torque (N·m)

Nr: Slip rotation speed of powder clutch/brake (r/min)
(This is the slip difference between the input and the output rotation speeds for the powder clutch, and the input rotation speed for the powder brake.)

Refer to the catalog for the allowable rotation speed, rated torque, and allowable continuous heat dissipation of each model.

24.2 When used for tension control

1. Machine specifications and selection calculation

Fig. 1 shows the flow chart for selecting the powder clutch/brake capacity when using it for tension control. When selecting a powder clutch/brake model, it is necessary to consider the three points of (1) torque, (2) rotation speed, and (3) heat dissipation (heat generation due to slip). These points are calculated from the machine specifications (tension, line speed, and reel diameter or roll diameter) by the following formula.

(1) Torque T

$$T = F \times \frac{D}{2} \quad (N \cdot m) \quad \cdots\cdots (1)$$

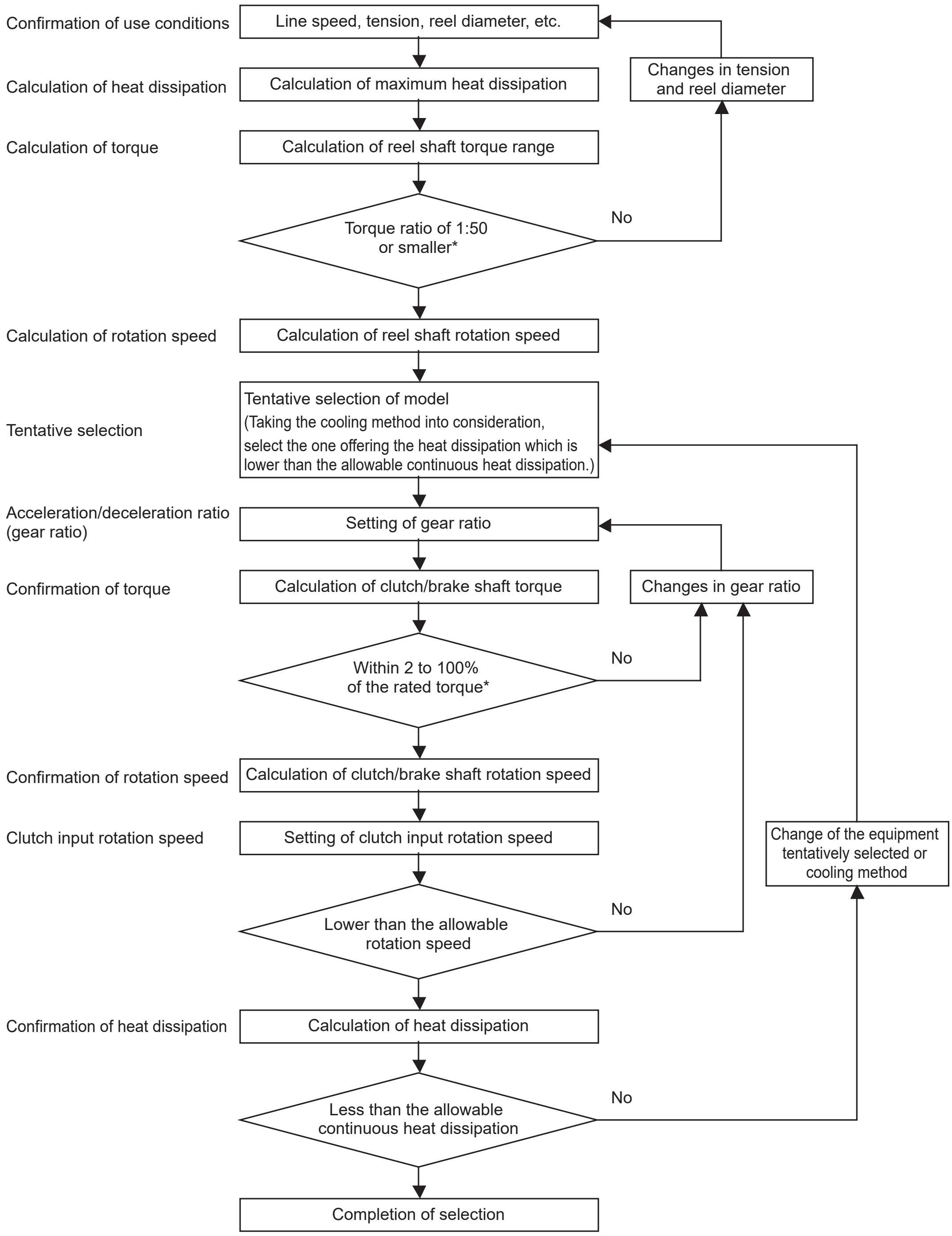
(2) Rotation speed N

$$N = \frac{V}{\pi \times D} \quad (r/min) \quad \cdots\cdots (2)$$

(3) Heat dissipation (heat generation) P

$$P = 0.105 \times T \times Nr \ (W) \quad \cdots\cdots (3)$$

F: Tension (N)
V: Line speed (m/min)
D: Raw web reel diameter or roll diameter (m)
Nr: Slip rotation speed of powder clutch/brake (r/min) (This is the slip difference between the input and the output rotation speeds for the powder clutch, and the input rotation speed for the powder brake.)



* The allowable torque control range varies depending on the model. For details, please see the catalog, etc.

Fig. 1 Powder clutch/brake selection flowchart

When a powder brake for unwinding is used

If connecting a powder brake (gear ratio = 1) directly to an unwinding reel, the slip rotation speed Nr is as follows:

Nr = (input rotation speed of powder brake)
= (unwinding reel rotation speed **N**)

Therefore, the calculation formula (3) for heat dissipation (heat generation) is as follows:

$$P = 0.105 \times T \times Nr$$
$$= 0.105 \times \left(F \times \frac{D}{2}\right) \times \left(\frac{V}{\pi \times D}\right)$$
$$= 0.0167 \times F \times V \quad \text{....................(4)}$$

It can be seen that heat dissipation (heat generation) is determined by the machine tension and line speed and is not affected by the reel diameter.

When a winding powder clutch is used

If connecting a powder brake (gear ratio = 1) directly to a winding reel, slip rotation speed Nr is as follows:

Nr = (input rotation speed of powder clutch $\mathbf{N_{input}}$)
- (winding reel rotation speed **N**)

Normally, the input rotation speed of the powder clutch is set to a constant rotation speed of 15 r/min or more than the maximum rotation speed of the winding reel. The heat dissipation (heat generation) is also changed by the change of the reel diameter (rotation speed of the winding reel). So, the maximum heat dissipation during operation is calculated by the following formula.

$$P_{max} = 0.105 \times T_{max} \times Nr_{max}$$
$$= 0.105 \times T_{max} \times \left(N_{input} - N_{min}\right) \quad \text{............(5)}$$

P_{max}: Maximum heat dissipation (W)
T_{max}: Maximum torque (N·m)
Nr_{max}: Maximum slip rotation speed (r/min)
N_{input}: Clutch input rotation speed (r/min)
N_{min}: Minimum clutch output rotation speed (r/min)

Normally, the torque and slip rotation speed are at their maximum just before the end of winding (when the diameter of the raw web is at its maximum), and the heat dissipation (heat generation) at this time is also at its maximum.
Note: If performing taper tension control during winding and the tension at the end of winding is significantly reduced compared to the tension at the start of winding, heat dissipation may be at its maximum during winding and not at the end of winding.
Normally, even with the same machine, the heat dissipation (heat generation) of a powder clutch for winding is higher than that of the powder brake used for unwinding. For this reason, it is necessary to select a model with a large allowable continuous heat dissipation, such as that with a larger torque size or a different cooling method.

Based on these calculation results, select the powder clutch/brake in accordance with the flow shown in Fig. 1.

2. Points of selection and points to be noted

The precautions listed below are particularly important when using the powder clutch/brake for tension control.

(a) Torque

Although the controllable range is approx. 2 to 100% of the rated torque (from idling torque to rated torque)*, controllability is superior when used in a range that is as close to the rated torque as possible. In particular, when the control unit uses an open-loop system such as a reel diameter detection type or manual type, it is recommended to use it in a range of 5 to 100%, which excels in linearity of the excitation current-torque characteristics.

* Because idling torque will vary depending on the model, refer to the catalog when making an actual selection.

(b) Rotation speed

In consideration of controllability, a slip rotation speed of 15 r/min or more must be ensured.
Even in the case of machines with slow line speeds, using a winding side powder clutch will not present any problems as long as the input rotation speed is set high and a slip rotation speed of 15 r/min or more can be ensured.
However, if a powder brake is used on the unwinding side of a machine with a slow line speed, the rotation speed (= slip rotation speed) of the powder brake will be determined by machine specifications, making it impossible to ensure a slip rotation speed of 15 r/min or more. In such cases, use a powder clutch rather than a powder brake and secure slip rotation speeds by applying rotation in the direction opposite to the direction of rotation of the unwinding reel using a geared motor or the like. (This is generally referred to as "Reverse input usage." Refer to "18. Usage at low rotation speeds" (page 30).
By normally applying reverse rotation, it is possible to control tension even when material feeding is stopped. This makes it possible to prevent material slack when stopped.
(ZKB, ZKG, and ZX powder clutches/brakes can be used from a rotation speed of approx. 5 r/min or more.)

3. Example of calculation for selecting a powder clutch/brake for tension control

Unwinding side powder brake (1)

What kind of powder brake should be used as the unwinding side brake with the film winding machine with the following specifications?

(1) Specifications

Line speed	V:	170 m/min constant
Tension	F:	100 N constant
Unwinding roll diameter	D_1:	660 mm
	D_2:	110 mm

(2) Calculation

(i) Torque

Suppose the brake torques required at the beginning and end of unwinding at tension 100 N are T_1 and T_2.

$$T_1 = \frac{D_1}{2} \times F = \frac{660 \times 10^{-3}}{2} \times 100 = 33\ \text{N·m}$$

$$T_2 = \frac{D_2}{2} \times F = \frac{110 \times 10^{-3}}{2} \times 100 = 5.5\ \text{N·m}$$

(ii) Rotation speed

Suppose the slip rotation speeds of the brake at the beginning and end of unwinding at a line speed of 170 m/min are N_1 and N_2.

$$N_1 = \frac{V}{\pi D_1} = \frac{170}{\pi \times 660 \times 10^{-3}} = 82\ \text{r/min}$$

$$N_2 = \frac{V}{\pi D_2} = \frac{170}{\pi \times 110 \times 10^{-3}} = 492\ \text{r/min}$$

(iii) Heat dissipation

Heat dissipation P is:

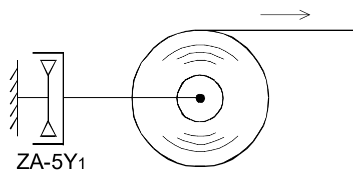
$$P = 0.105 \times T \times Nr = 0.105 \times \frac{DF}{2} \times \frac{V}{\pi D}$$
$$= 0.0167 \times F \times V = 0.0167 \times 100 \times 170$$
$$= 284\ \text{W}$$

As shown above, the continuous heat dissipation of the unwinding side brake at constant line speed and constant tension becomes constant.

(iv) Selection

In view of the torque (T_1, T_2) and heat dissipation (P), the ZA-5Y_1 (allowable continuous heat dissipation approx. 290 W at rated torque 50 N·m and input rotation speed 82 r/min) can be used with natural cooling.

The unwinding reel and brake shaft are directly connected, and the torque usage range is 66 to 11% of the rating.



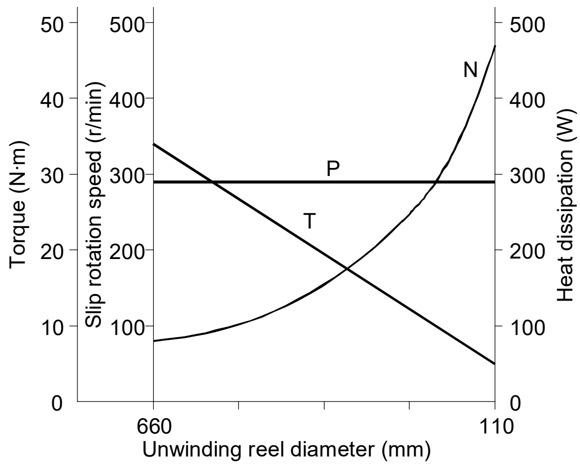


Fig. 1 Unwinding reel diameter vs. torque characteristics, etc.

[Reference]

The allowable continuous heat dissipation of natural cooling varies depending on the rotation speed of the brake, so decide whether to use one while the brake is at low rotation (N_1) when the allowable continuous heat dissipation becomes small.

Unwinding side powder brake (2)

What kind of powder brake should be used as the unwinding side brake of a paper coating machine with the following specifications?

(1) Specifications

Line speed	V:	100 to 250 m/min
Tension	F:	150 to 300 N
Unwinding roll diameter	D_1:	900 mm
	D_2:	110 mm

(2) Calculation

(i) Torque

Suppose the brake torques required at the beginning and end of unwinding at tension 150 to 340 N are T_1 and T_2.

$$T_1 = \frac{D_1}{2} \times F = \frac{900 \times 10^{-3}}{2} \times (150 \text{ to } 300)$$
$$= 67.5 \text{ to } 135 \text{ N·m}$$

$$T_2 = \frac{D_2}{2} \times F = \frac{110 \times 10^{-3}}{2} \times (150 \text{ to } 300)$$
$$= 8.25 \text{ to } 16.5 \text{ N·m}$$

(ii) Rotation speed

Suppose the slip rotation speed at the beginning of winding at a line speed of 100 to 250 m/min is N_1 and the slip rotation speed at the end of unwinding is N_2.

$$N_1 = \frac{V}{\pi D_1} = \frac{100 \text{ to } 250}{\pi \times 900 \times 10^{-3}} = 35 \text{ to } 88 \text{ r/min}$$

$$N_2 = \frac{V}{\pi D_2} = \frac{100 \text{ to } 250}{\pi \times 110 \times 10^{-3}} = 290 \text{ to } 724 \text{ r/min}$$

(iii) Heat dissipation

Determine the maximum line speed and maximum tension.

$$P = 0.105 \times T \times Nr = 0.0167 \times F \times V = 1{,}253 \text{ W}$$

From the above calculation results, it is possible to use the following brake in consideration of the torque capacity and the heat dissipation.

Forced air cooling: ZKB-20XN (rated torque 200 N·m, allowable continuous heat dissipation 1,400 W) can be used by being connected directly.

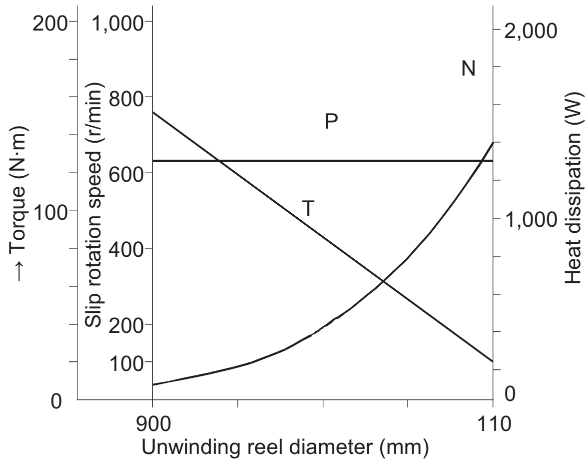


Fig. 1 Unwinding reel diameter vs. torque characteristics, etc.

Unwinding side powder brake (3)

Next is an example of changing the gear ratio according to the tension when the torque control range is wide.

(1) Specifications

Line speed	V: 100 m/min constant
Tension	F: 130 to 520 N
Unwinding roll diameter	D: 100 mm to 900 mm
Manual control	

(2) Calculation

(i) As in the previous example, calculate the torque (T), rotation speed (N), and heat dissipation (P) of the unwinding reel.

$$T = \frac{D}{2} \times F = \frac{(0.1 \text{ to } 0.9)}{2} \times (130 \text{ to } 520)$$

$$= 6.5 \text{ to } 234 \text{ N·m}$$

$$N = \frac{V}{\pi D} = \frac{100}{\pi \times (0.1 \text{ to } 0.9)}$$

$$= 35.4 \text{ to } 318 \text{ r/min}$$

$$P = 0.0167 \times F \times V = 868 \text{ W (maximum)}$$

Based on the above calculations, the ZKB-10HBN (thermoblock cooling type) is used.

(ii) Here, suppose the torque of 234 N·m is 100%, the torque obtained above is 2.8% with 6.5 N·m, and it is out of the control range (5 to 100%) in manual control.
Therefore, it is necessary to change the gear ratio according to the tension and set it to the appropriate torque range.
The branch value (Fm) of tension is determined by the following formula.

$$Fm = \sqrt{\text{Tension ratio}} \times Fmin$$

$$= \sqrt{\frac{520}{130}} \times 130 = 260$$

(iii) When tension is 130 to 260 N
Unwinding reel

$$Tbo = \frac{(0.1 \text{ to } 0.9)}{2} \times (130 \text{ to } 260)$$

$$= 6.5 \text{ to } 117 \text{ N·m}$$

Nbo = N = 35.4 to 318 r/min

Brake shaft (1.17 times increase in speed)

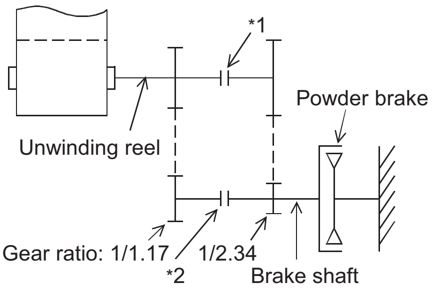
$$Tbr = Tbo \times \frac{1}{1.17} = 5.6 \text{ to } 100 \text{ N·m}$$

(5.6 to 100%)

Nbr = Nbo × 1.17 = 41.4 to 372 r/min
P = 0.0167 × F × V = 434 W (maximum)

(iv) When tension is 260 to 520 N (calculated as in the previous example)
Unwinding reel
Tbo = 13 to 234 N·m
Nbo = 35.4 to 318 r/min
Brake shaft (2.34 times increase in speed)
Tbr = 5.6 to 100 N·m
Nbr = 82.8 to 744 r/min
P = 868 W (Maximum)

(v) Configuration example



Note 1. Acceleration ratios 1.17 and 2.34 are the ones to set the maximum torque of each to be 100%.

Note 2. Since increasing the number of engagements to gain a large acceleration (deceleration) ratio lowers the transmission efficiency and makes accurate torque control difficult, set the number of engagements to one.

*1 and *2 are electromagnetic clutches etc.,
When F = 130 to 260 N
*1: OFF
*2: ON→Gear ratio becomes $\frac{1}{1.17}$
When F = 260 to 520 N
*1: ON
*2: OFF→Gear ratio becomes $\frac{1}{2.34}$

Winding side powder clutch (1)

(1) Specifications

Line speed	V	: 100 m/min constant
Tension	F	: 180 N constant
Winding roll diameter	D_1	: 90 mm
	D_2	: 540 mm

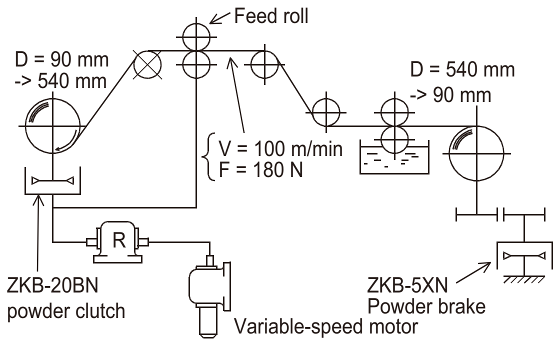


Fig. 1 Configuration diagram

(2) Calculation

(i) Torque

Suppose the clutch torques required at the beginning and end of winding at a tension of 180 N are T_1 and T_2.

$$T_1 = \frac{D_1}{2} \times F = \frac{90 \times 10^{-3}}{2} \times 180 = 8.1 \text{ N·m}$$

$$T_2 = \frac{D_2}{2} \times F = \frac{540 \times 10^{-3}}{2} \times 180 = 48.6 \text{ N·m}$$

(ii) Rotation speed

Suppose the rotation speeds at the beginning and end of winding at a line speed of 100 m/min are N_1 and N_2 (N_1 and N_2 are the rotation speeds of the winding reel, not the slip rotation speeds).

$$N_1 = \frac{V}{\pi D_1} = \frac{100}{\pi \times 90 \times 10^{-3}} = 354 \text{ r/min}$$

$$N_2 = \frac{V}{\pi D_2} = \frac{100}{\pi \times 540 \times 10^{-3}} = 59 \text{ r/min}$$

(3) Heat dissipation

If the input rotation speed N_0* of the clutch is made higher by 15 r/min than the rotation speed N_1 necessary at the beginning of winding of the winding reel, the heat dissipation P_1 and P_2 of the clutch at the beginning and end of winding are as follows:

$P_1 = 0.105 \times (369 - 354) \times 8.1 = 12.8$ W

$P_2 = 0.105 \times (369 - 59) \times 48.6 = 1,582$ W

As shown, when it is used as a winding clutch with constant tension, both the slip rotation speed and winding torque become the maximum at the end of winding. Thus, the heat dissipation also becomes the maximum at the end of winding, and therefore the heat capacity of the clutch must be determined in the final state of winding.

Based on the above calculation results, the model name is selected as follows.

Forced air cooling type: ZKB-20BN (Rated torque of 200 N·m, allowable continuous heat dissipation of 1,900 W) can be used. However, if it is directly connected to the winding reel, the torque will be 5% or less of the rated torque at the beginning of winding, so it should be controlled automatically.

Examination of the unwinding side turns out as follows:

$$\begin{cases} N_1 = 354 \text{ r/min} \\ N_2 = 59 \text{ r/min} \end{cases} \quad \begin{cases} T_1 = 8.1 \text{ N·m} \\ T_2 = 48.6 \text{ N·m} \end{cases}$$

This is the same as the winding side.

Heat dissipation P is:

$P = 0.105 \times T_1 \times N_1 = 0.105 \times T_2 \times N_2$

$= 0.0167 \times F \times V = 301$ W

The above results show the following:

Natural cooling: ZKB-20XN (rated torque 200 N·m, approx. 380 W at an allowable continuous heat dissipation near 59 r/min) can be used.

Forced air cooling: ZKB-5XN (rated torque 50 N·m, allowable continuous heat dissipation 700 W) can be used.

As is clear from the above calculation results, the torque operating ranges and the slip rotation speeds are not much different between the clutch for winding and the brake for unwinding, but the heat dissipations are significantly different. Note that, for this reason, the selected model will change. The heat dissipation on the unwinding side is constant regardless of the winding ratio (the ratio of the minimum diameter to the maximum diameter), but on the winding side, the heat dissipation increases substantially in proportion to the winding ratio.

* The clutch input rotation speed N_0 was increased by 15 r/min, but normally it should be approx. 10% higher. For the brake, ZA-5Y_1 blower cooling can be used.

Powder clutch for driving pinch roll

(1) Specifications

Roll diameter D: 200 mm
Line speed V: 45 to 90 m/min
Tension F: 100 to 350 N

When the decorative sheet is bonded to the plywood, the pinch roll B, with respect to the feed roll A, has a difference in circumferential speed due to a change in the rubber roll diameter by the pinch pressure conduction. To prevent the peripheral speed difference from causing roll B to slip, a powder clutch is put into the drive system of roll B to let the slipping occur in the clutch.

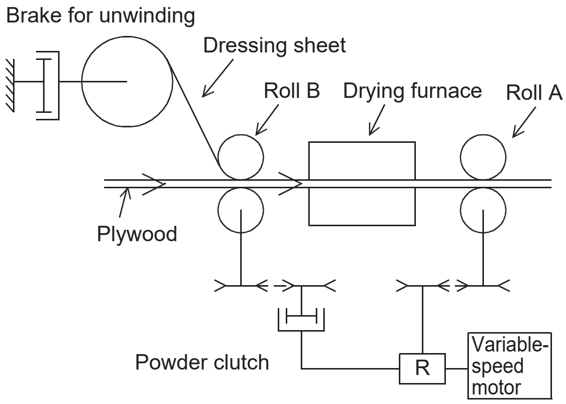


Fig. 1 Configuration diagram

(2) Calculation

(i) Rotation speed of roll B

$$N = \frac{V}{\pi D} = \frac{45 \text{ to } 90}{\pi \times 200 \times 10^{-3}} = 72 \text{ to } 144 \text{ r/min}$$

(ii) Roll driving torque

$$T = \frac{D}{2} \times F = \frac{200 \times 10^{-3}}{2} \times (100 \text{ to } 350)$$
$$= 10 \text{ to } 35 \text{ N·m}$$

(iii) Heat dissipation

When the input rotation speed of the clutch is decided so that the slip rotation speed becomes 15 r/min when the line speed is 45 m/min, the maximum heat dissipation is as follows.

The input rotation speed N_0 of the clutch at 90 m/min is:

$$N_0 = 144 \times \left(\frac{72 + 15}{72}\right) \approx 144 \times 1.2 = 173 \text{ r/min}$$
$$P = 0.105 \times (173 - 144) \times 35 = 107 \text{ W}$$

Based on the above calculation results, use ZA-2.5A1 (rated torque 25 N·m, heat dissipation 240 W at 200 r/min) where the speed has been doubled from the roll B shaft.

In this case, the operating range of the torque becomes 5 to 17.5 N·m, and the input rotation speed N_0' of the clutch will be enough if it is:

$$N_0' = 288 \times \left(\frac{144 + 15}{144}\right) \approx 318 \text{ r/min}$$

The heat dissipation at this time is:

$$P = 0.105 \times (318 - 288) \times 17.5 = 55 \text{ W}$$

Constant slip control of the winding side powder clutch

Although powder clutches are often used to control the tension of various winders, there are many cases (for example, that shown in Fig. 1) in which the optimal model cannot be selected because the heat generated during operation exceeds the allowable continuous heat dissipation of the powder clutch.
In such cases, it is possible to reduce the heat dissipation by reducing the input rotation speed of the clutch by using a tension controller (e.g., LE7-40GU-L+ LE7-DCA or LD-10WTB-CCL) and an inverter capable of calculating the reel diameter (refer to Fig. 2).
Fig. 2 shows an example in which the inverter is controlled by speed output signals from LE7-40GU-L+LE7-DCA or LD-10WTB-CCL to keep the slip rotation speed constant. (Constant slip control is achieved by gradually reducing the clutch input rotation speed as the winding reel diameter increases.)
Fig. 3 shows a configuration example of open-loop control performed via reel diameter detection. Fig. 4 shows an example in which feedback control is performed using a tension detector.

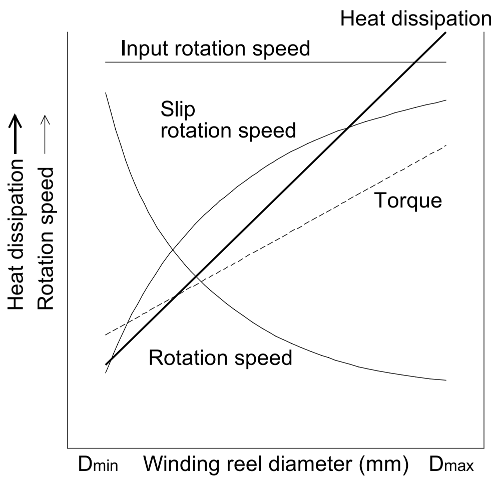


Fig. 1 Description of operation
(when input rotation speed is fixed)

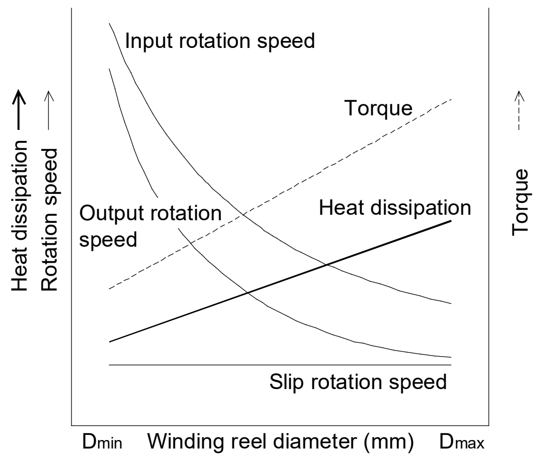


Fig. 2 Description of operation
(during constant slip control)

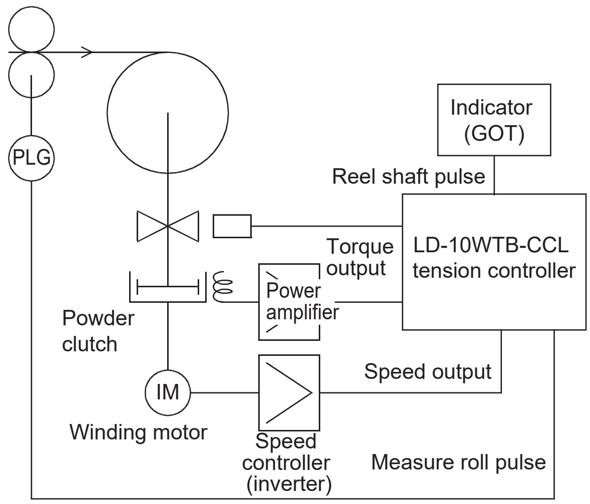


Fig. 3 Configuration example (open-loop control)

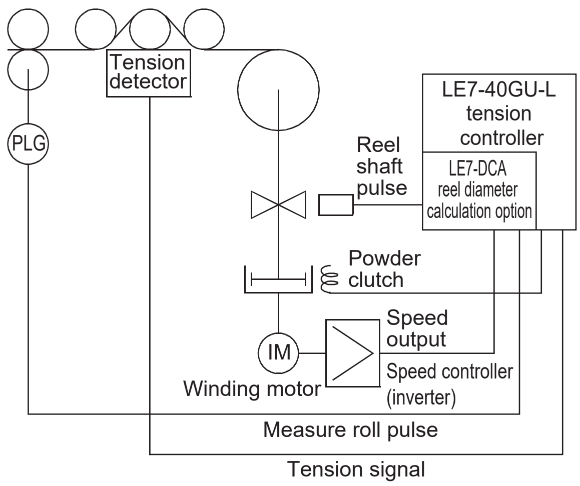


Fig. 4 Configuration example (feedback control)

(1) Specifications (same specifications as “Winding side powder clutch (1)”)

Line speed	V: 120 m/min constant
Tension	F: 180 N constant
Winding roll diameter	D_1: 90 mm
	D_2: 540 mm

The following is true if the configuration examples in Figs. 1 and 2 are used.

(2) Calculation

(i) Torque

Supposing the clutch torques required at the beginning and end of winding at a tension of 180 N are T_1 and T_2, it is the same as for “Winding side powder clutch (1).”

$$T_1 = \frac{D_1}{2} \times F = \frac{90 \times 10^{-3}}{2} \times 180 = 8.1\ \text{N·m}$$

$$T_2 = \frac{D_2}{2} \times F = \frac{540 \times 10^{-3}}{2} \times 180 = 48.6\ \text{N·m}$$

(ii) Rotation speed

The rotation speeds at the beginning and end of winding at a line speed of 120 m/min (N_1 and N_2) are also the same as for “Winding side powder clutch (1).”

$$N_1 = \frac{V}{\pi D_2} = \frac{120}{\pi \times 90 \times 10^{-3}} = 425\ \text{r/min}$$

$$N_2 = \frac{V}{\pi D_2} = \frac{120}{\pi \times 540 \times 10^{-3}} = 71\ \text{r/min}$$

(iii) Heat dissipation

If the input rotation speed N_0 of the clutch is made higher by 15 r/min than the rotation speed N_1 necessary at the beginning of winding of the winding reel by controlling the inverter using a LE7-40GU-L+LE7-DCA or LD-10WTB-CCL tension controller, the heat dissipation P_1 and P_2 of the clutch at the beginning and end of winding are as follows:

$P_1 = 0.105 \times 15 \times 8.1 = 12.8$ W

$P_2 = 0.105 \times 15 \times 48.6 = 76.5$ W

When compared with the heat dissipation of 1,883 W (Winding side powder clutch (1)) as a result of fixing the input rotation speed in this way:

76.5 W / 1,883 W = 0.04 = 4%

If the heat dissipation is reduced to 4% as shown above and a powder clutch is selected:

Natural cooling type: ZKB-5BN

(rated torque 50 N·m, 260 W at an allowable continuous heat dissipation near 71 + 15 = 86 r/min) can be used.

Also, because the minimum torque used is 8.1 / 50 = 16.2% ≥ 5%, both open-loop control and feedback control are possible.

As is clear from the above calculation results, if a powder clutch is used on the winding side, controlling the inverter of the winding reel using a LE7-40GU-L+LE7-DCA or LD-10WTB-CCL tension controller has advantages such as the following:

- It may be possible to perform selection using fixed input rotation speed.
- It may be possible to use a smaller type of powder clutch, which would improve control accuracy.
- It may be possible to use open-loop control to operate machines for which only feedback control could be selected.
- It may be possible to extend the lifespan of the powder clutch if the same clutch is used.

Using two unwinding side powder brakes in parallel

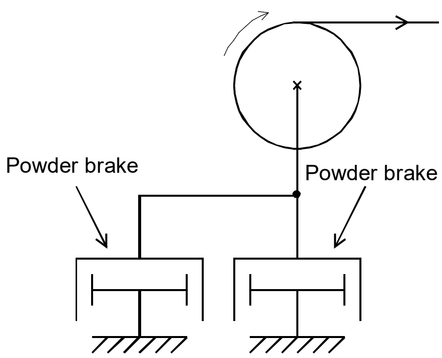
Two powder brakes may be installed in parallel on one unwinding reel if tension and line speed are high, if the torque and heat dissipation (heat generation) are high when performing calculations for selection of a powder brake, or if capacity is insufficient just using one powder brake. When doing so, it is necessary to perform selection calculations by considering variations in the torque of the two powder brakes.
Normally, when using two powder brakes in parallel, the same current (voltage) is applied to both powder brakes. For this reason, any variation in torque between the two powder brakes will prevent the required torque from being evenly shared by the two powder brakes, causing a large amount of torque to be output. As a result, the powder brake on the side with the larger torque will bear much of the torque, causing the heat dissipation (heat generation) to also increase. Therefore, if the total allowable continuous heat dissipation of the two units is selected without providing a margin for heat dissipation during operation, there is a possibility that the allowable value will be exceeded for the powder brake on the side with the larger torque.
For this reason, selections are to be made by providing a margin of 20% for rated torque and allowable continuous heat dissipation.

Selection example

(1) Specifications

Line speed	V: 350 m/min
Tension	F: 400 to 600 N
Unwinding roll diameter	D_1: 1,000 mm
	D_2: 100 mm

Other conditions
Set the gear ratio of the unwinding reel and the brake shaft to R=1 and use ZKB-HBN powder brakes.



(2) Calculation

Torque
Assuming that the required brake torque at the beginning of unwinding and the required brake torque at the end of unwinding are T_1 and T_2 respectively,

$$T_1 = F \times \frac{D_1}{2} = (400 \text{ to } 600) \times \frac{1,000 \times 10^{-3}}{2} = 200 \text{ to } 300 \quad (\text{N·m})$$

$$T_2 = F \times \frac{D_2}{2} = (400 \text{ to } 600) \times \frac{100 \times 10^{-3}}{2} = 20 \text{ to } 30 \quad (\text{N·m})$$

Rotation speed
Assuming that the rotation speed of the unwinding reel at the beginning of unwinding and the rotation speed of the unwinding reel at the end of unwinding are N_1 and N_2 respectively,

$$N_1 = \frac{V}{\pi \times D_1} = \frac{350}{\pi \times 1,000 \times 10^{-3}} = 111 \quad (\text{r/min})$$

$$N_2 = \frac{V}{\pi \times D_2} = \frac{350}{\pi \times 100 \times 10^{-3}} = 1114 \quad (\text{r/min})$$

Maximum heat dissipation

$$P_{max} = 0.0167 \times F_{max} \times V_{max} = 0.0167 \times 600 \times 350 = 3,507 \quad (\text{W})$$

By dividing the torque and heat dissipation between the two powder brakes and providing a margin of 20%,
Required torque for each powder brake

$$T = \frac{T_{max}}{2} \times 1.2 = \frac{300}{2} \times 1.2 = 180 \quad (\text{N·m})$$

Required heat dissipation for each powder brake

$$P = \frac{P_{max}}{2} \times 1.2 = \frac{3,507}{2} \times 1.2 = 2,104 \quad (\text{W})$$

Accordingly, select ZKB-20HBN (rated torque: 200 N·m, allowable continuous heat dissipation: 2,800 W).

Using the powder clutch for reverse input on the unwinding side

When selecting an unwinding powder brake, if the line speed of the machine is slow and a sufficient slip rotation speed cannot be secured, it is possible to use the powder clutch for reverse input.
The output side (or input side) of the powder clutch is engaged to the unwinding reel, a device such as a geared motor is connected to the input side (or output side), and the unwinding wheel is always rotated in the direction opposite the rotation direction.
Doing so makes it possible to secure a sufficient slip rotation speed and enables stable torque control.

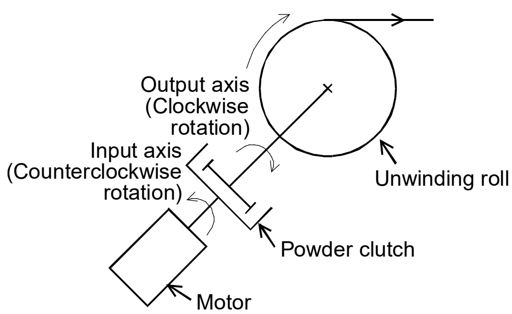
As for the mounting directions of the input and output sides of the clutch, the input side of the clutch is usually engaged with the side with the higher rotation speed.
In other words, if the line speed is slow and the rotation speed of the unwinding reel is always low, the input side of the clutch is to be engaged with the motor.
If the diameter at the start of unwinding is large and rotation is only temporarily slowed at the start of unwinding, the output side is to be engaged with the motor for most operating hours providing a sufficient slip rotation speed can be obtained.

Selection example

(1) Specifications

Line speed	V: 1 to 5 m/min
Tension	F: 50 to 100 N
Unwinding roll diameter	D_1: 400 mm
	D_2: 110 mm

Other conditions
Set the gear ratio of the unwinding reel and the brake shaft to R=1.



(2) Calculation

Torque
Suppose the required brake torque at the beginning of unwinding and the required brake torque at the end of unwinding are T_1 and T_2,

$$T_1 = F \times \frac{D_1}{2} = (50 \text{ to } 100) \times = \frac{400 \times 10^{-3}}{2} = 10 \text{ to } 20 \quad (\text{N·m})$$

$$T_2 = F \times \frac{D_2}{2} = (50 \text{ to } 100) \times \frac{110 \times 10^{-3}}{2} = 2.75 \text{ to } 5.5 \quad (\text{N·m})$$

Rotation speed
Suppose the rotation speed of the unwinding reel at the beginning of unwinding and the rotation speed of the unwinding reel at the end of unwinding are N_1 and N_2,

$$N_1 = \frac{V}{\pi \times D_1} = \frac{(1 \text{ to } 5)}{\pi \times 400 \times 10^{-3}} = 0.8 \text{ to } 4.0 \quad (\text{r/min})$$

$$N_2 = \frac{V}{\pi \times D_2} = \frac{(1 \text{ to } 5)}{\pi \times 110 \times 10^{-3}} = 2.9 \text{ to } 14.5 \quad (\text{r/min})$$

Maximum heat dissipation P_{max} is:

$$P_{max} = 0.0167 \times F_{max} \times V_{max} = 0.0167 \times 100 \times 5 = 3.35 \text{ (W)}$$

By using a geared motor and applying a rotation of N_{rev} = 30 r/min in the direction opposite the unwinding reel rotation direction, the heat dissipation of the reverse rotation P_{rev} is:

$$P_{rev} = 0.105 \times T_{max} \times N_{rev} = 0.105 \times 20 \times 30 = 63 \text{ (W)}$$

As a result, the maximum heat dissipation P_{sum} is:
$$P_{sum} = P_{max} + P_{rev} = 3.35 + 63 = 66.35 \text{ (W)}$$

Select ZKB-2.5BN (rated torque: 25 N·m, allowable continuous heat dissipation: 120 W).

Note. Although controllability will be better at higher slip rotation speeds, heat dissipation (heat generation) will also increase accordingly. During actual use, set the reverse input rotation speed to approx. 50 r/min.

Powder clutches/brakes for intermediate shaft control

The powder clutch and brake are used simultaneously for in-feed and out-feed tension control of the intermediate shaft. (However, if conditions are limited, control can be performed using only the powder brake in the case of in-feed control and only with the powder clutch in the case of out-feed control.)

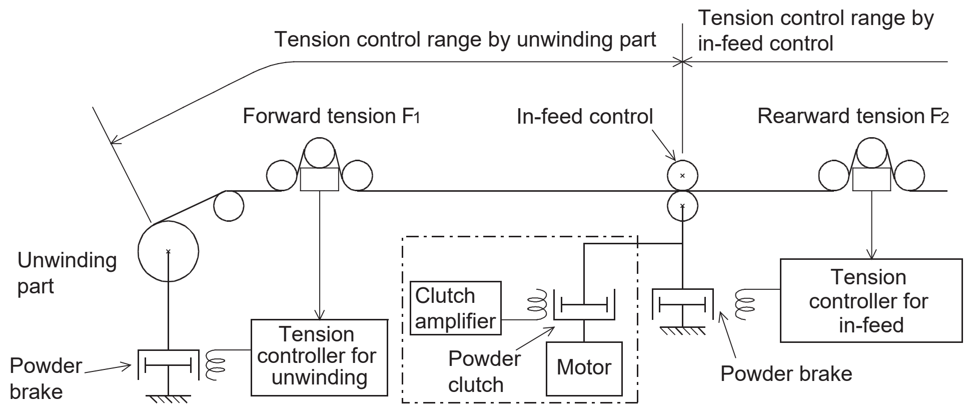
In-feed control

As shown in the figure, the powder clutch is driven with a constant torque in the direction of material feeding, while tension is controlled by controlling the torque of the powder brake.
Calculate the required torque by calculating the difference in tension before and after the feed roll, not by calculating the target tension to be controlled. Since this difference in tension is controlled by the powder clutch brake attached to the feed roll, the tension F when calculating the torque of the powder clutch brake is F = (forward tension F_1) - (rearward tension F_2).
Control is possible only using a powder brake when the rearward tension F_2 is always larger than the forward tension F_1 ($F_1 < F_2$).
(A powder clutch and clutch amplifier are not necessary.)

Selection example

(1) Specifications

Line speed	V: 120 m/min
Forward (unwinding) tension	F_1: 100 N
Rearward tension	F_2: 50 to 140 N
Feed roll diameter	D: 110 mm



To control the rearward tension F_2 within a tension range of 50 to 140 N when the forward tension F_1 = 100 N, the tension of the feed roll section must be adjusted to be within a range of F = -50 to 40 N. For that purpose, a constant torque of 50 N (in the same direction as the feed direction) is applied using the powder clutch and a brake of 10 to 100 N is applied using the powder brake to adjust the forward tension F_1 between -50 to 40 N to enable the rearward tension F_2 to be controlled within a range of 50 to 140 N.

(2) Calculation
Rotation speed N of the feed roll is:

$$N = \frac{V}{\pi \times D} = \frac{120}{\pi \times 110 \times 10^{-3}} = 347 \quad \text{(r/min)}$$

Powder clutch selection

The required torque when feeding at 50 N with the powder clutch is:

$$T_{cl} = F_{cl} \times \frac{D}{2} = 50 \times \frac{110 \times 10^{-3}}{2} = 2.75 \quad (N \cdot m)$$

Because the input side of the clutch must be rotated at a rotation speed faster than the rotation speed of the feed roll (347 r/min), the rotation speed of the clutch drive motor is set to 400 r/min.

$$T_{cl} = 0.105 \times T \times (N_{input} - N_{output})$$
$$= 0.105 \times 2.75 \times (400 - 347) = 15.3 \text{ (W)}$$

Based on the above, select ZKB-0.3AN (rated torque: 3 N·m, allowable continuous heat dissipation: 50 W) for the powder clutch.

Powder brake selection

The required brake torque to apply a tension of 10 to 100 N is:

$$T_{br} = F_{br} \times \frac{D}{2} = (10 \text{ to } 100) \times \frac{110 \times 10^{-3}}{2}$$
$$= 0.55 \text{ to } 5.5 \quad (N \cdot m)$$

Maximum heat dissipation P_{max} is:

$$P_{max} = 0.0167 \times F_{max} \times V = 0.0167 \times 100 \times 120$$
$$= 200 \text{ (W)}$$

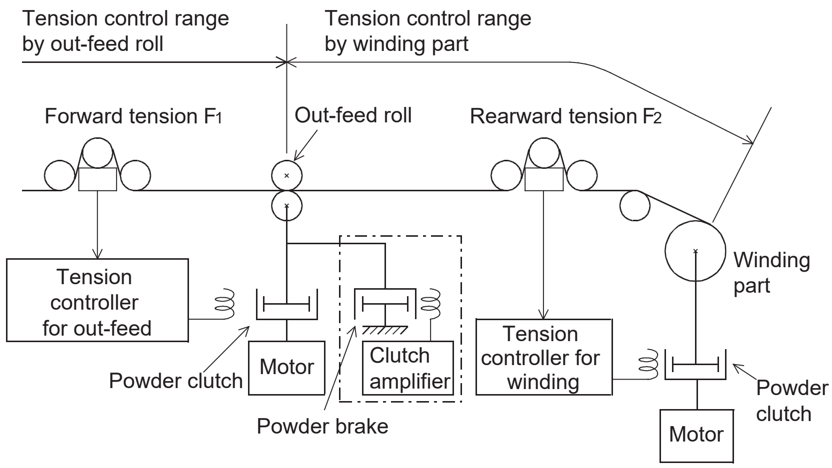
Based on the above, select ZA-1.2Y_1 (rated torque: 12 N·m, allowable continuous heat dissipation: 220 W) for the powder brake.

If the rearward tension F_2 is in a range that exceeds 100 N (e.g., 110 to 160 N), a powder clutch is unnecessary and control is possible using only a powder brake.

By using this powder clutch and brake configuration for the unwinding part, unwinding mechanical loss can be cancelled and tension control can be achieved using a low tension and without the effects of mechanical loss.

Out-feed control

In the case of out-feed control, contrary to in-feed control, tension is controlled by setting the powder brake to a constant torque and controlling the torque of the powder clutch.
Calculations for the required torque are also contrary to that for in-feed control in that the tension F used for calculation is F = (rearward tension F_2) - (forward tension F_1).
Control is possible using only a powder clutch when the forward tension F_1 is always larger than the rearward tension F_2 ($F_1 > F_2$). (A powder brake and clutch amplifier are not necessary.)



Selection example

(1) Specifications

Line speed	V: 120 m/min
Forward tension	F_1: 80 N
Rearward (winding) tension	F_2: 100 → 50 N (Perform taper control so that winding starts at a tension of 100 N and reaches 50 N at the end of winding.)
Feed roll diameter	D: 110 mm

Because rearward tension F_2 will exceed forward tension F_1 after winding starts at 100 N and until 80 N, it is necessary to install a powder brake, as tension control using only a powder clutch will not be possible. By using this powder brake to apply a brake of 30 N and using the powder clutch to change the tension from 10 to 60 N, forward tension F_1 can be controlled to remain constant at 80 N even if the rearward (winding) tension F_2 changes from 100 to 50 N.

(2) Calculation

Rotation speed N of the feed roll is:

$$N = \frac{V}{\pi \times D} = \frac{120}{\pi \times 110 \times 10^{-3}} = 347 \quad \text{(r/min)}$$

Powder brake selection

$$T_{br} = F_{br} \times \frac{D}{2} = 30 \times \frac{110 \times 10^{-3}}{2} = 1.65 \quad (\text{N·m})$$

Maximum heat dissipation P_{max} is:

$P_{max} = 0.0167 \times F_{max} \times V = 0.0167 \times 30 \times 120$

$= 60$ (W)

Select ZKB-0.6YN (rated torque: 6 N·m, allowable continuous heat dissipation: 70 W) for the powder brake.

Powder clutch selection

The required torque when feeding at 10 → 60 N with the powder clutch is:

$$T_{cl} = F_{cl} \times \frac{D}{2} = 10 \text{ to } 60 \times \frac{110 \times 10^{-3}}{2}$$

$$= 0.55 \text{ to } 3.3 \quad (\text{N·m})$$

Because the clutch input must be rotated at a rotation speed faster than the rotation speed of the feed roll (347 r/min), the rotation speed of the motor is set to 400 r/min.

$P_{cl} = 0.105 \times T \times (N_{input} - N_{output})$

$= 0.105 \times 3.3 \times (400 - 347) = 18.4$ (W)

Based on the above, select ZKB-0.6AN (rated torque: 6 N·m, allowable continuous heat dissipation: 70 W) for the powder clutch.

24.3 Using the powder clutch for engagement

1. Selection calculation

Usage as an engagement device
(a) Selection based on the motor
When the load torque is not clear and only the motor output is known, the following formula is to be used:

$$T_L = 9{,}550 \frac{P}{N} \eta \quad \text{.......................................}(1)$$

where,
- T_L: Load torque (N·m)
- P: Motor rated output (kW)
- N: Clutch shaft rotation speed (r/min)
- η: Machine conduction efficiency from motor shaft to clutch shaft

A clutch model with an expected safety factor of 1.5 to 3x the T_L is recommended.
When the load torque is known, select a model by multiplying the load torque by a safety factor of 1.5 to 3x to obtain the torque required for the clutch.

(b) Although the selection made in a) will be sufficient when using as a normal engagement device, it is necessary to consider the heat capacity especially when using a clutch or brake to start/stop a machine with a large moment of inertia *J* or under operating conditions in which the engaging frequency is high. When engaging the drive side idling at slip rotation speed Nr (r/min) with the driven side, the thermal energy (i.e., engaging energy E) generated on the friction surface is expressed by the following equation:

$$E = \frac{J \cdot Nr^2}{182} \cdot \frac{T_C}{T_C \pm T_L} \text{ (J)} \quad \text{..........................}(2)$$

Here, the “-” symbol represents accelerated engagement (at start up),
while the “+” symbol represents decelerated engagement (when stopping)

where,
- T_C: Clutch transmission torque (N·m) (brake torque in the case of a brake) Set to an appropriate value based on the excitation current.
- T_L : Load torque for clutch shaft conversion (N·m)
- *J* : Load moment of inertia for clutch shaft conversion (kgm²)

Engaging time is expressed by the following equation:

$$t = \frac{J \cdot Nr}{9.55 \times (T_C \pm T_L)} \text{ (S)} \quad \text{..........................} (3)$$

Here, the “-” symbol represents accelerated engagement, while the “+” symbol represents decelerated engagement.

Use equation (2) to find the engaging energy per engagement and examine the engaging frequency. If both are obtained, consider whether they are within the allowable engaging energy range as shown in the diagram in Fig. 1. If they are not with the specified range, a larger model must be selected even if transmission torque is sufficient.
Fig. 1 shows an energy diagram for when the rotation speed is N ≥ 1,000 r/min. Because the self-cooling effect due to rotation will decrease if N < 1,000 r/min, engaging energy is converted as follows:

$$E_N = E \times \frac{P}{P_N} \quad \text{..} (4)$$

- E_N: A value equivalently converted from the engaging energy at N rotation to N ≥ 1,000 r/min
- E: Engaging energy obtained with equation (2)
- P: Allowable continuous heat dissipation of each model when N ≥ 1,000 r/min
- P_N: Allowable continuous heat dissipation of each model when N r/min

Also, as can be seen from equation (3), the engaging time will vary depending on the value for T_C. Note that when using as a starting clutch, starting will not be possible if T_L is greater than T_C. If T_L is set as 0 when the load torque is negligible:

$$E = \frac{J \cdot Nr^2}{182} \text{ (J)} \quad \text{.......................................} (5)$$

Equation (5) is determined by the relative rotation speed, regardless of the load rotation status.

Also, if the engaging frequency is 50 times/hour or more, it is considered as continuous slip rather than intermittent slip, and calculated by the following formula:

$P = 2 \times E \times S$ (W) .... (6)
where, 2: Safety factor
E: Engaging energy obtain in equation (2) (J)
S: Engaging frequency (times/sec)

If P obtained in equation (6) is continuous slip, determine whether it is within the specified range for the allowable continuous heat dissipation of each model.

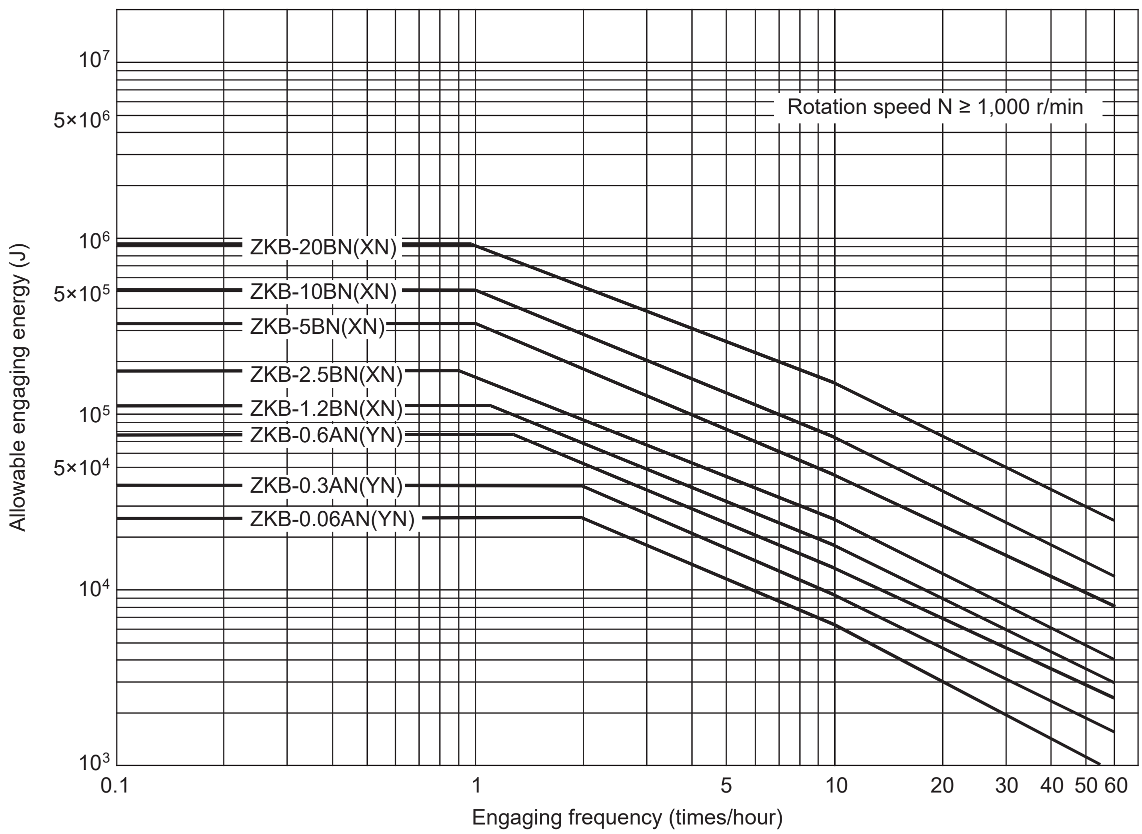


Fig. 1 ZKB clutch/brake allowable engaging frequency

2. Example calculation for selecting a powder clutch for engagement

Powder clutch for cushioned starting

The following shows an example in which a powder clutch is used for cushioned starting.

(1) Specifications

Load moment of inertia $J = 1.25 \times 10^2$ kgm^2

Load torque = 48 N·m

Startup time 10 s

Startup frequency 5 times/hour

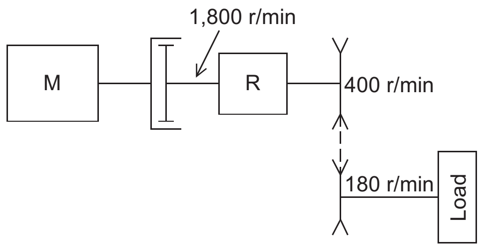


Fig. 1 Configuration example

(2) Calculation

Moment of inertia for clutch shaft conversion J

$$= 1.25 \times 10^2 \times \left(\frac{180}{1{,}800}\right)^2 = 1.25 \text{ kgm}^2$$

Load torque for clutch shaft conversion

$$= 48 \times \left(\frac{180}{1{,}800}\right)$$
$$= 4.8 \text{ N·m}$$

Required clutch torque T_C when the startup time is 10s is:

$$T_C = \frac{J}{t} \times \frac{Nr}{9.55} + T_L$$
$$= \frac{1.25}{10} \times \frac{1{,}800}{9.55} + 4.8 = 23.6 + 4.8 = 28.4 \text{ N·m}$$

At this time, engaging energy E per startup is:

$$E = \frac{28.4}{28.4 - 4.8} \times \frac{1.25 \times 1{,}800^2}{182} = 2.7 \times 10^4 \text{ J}$$

Based on the torque capacity, ZKB-5BN is required. Because the allowable engaging energy of ZKB-5BN is 8.0×10^4 J when started up 5 times per hour, the allowable value is satisfied.

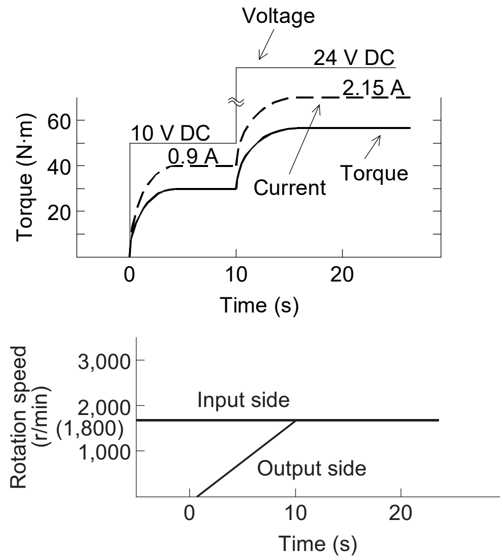


Fig. 2 Operation characteristics

Note 1. As shown in Fig. 2, after the cushioned start is completed, switch from weak excitation to rated excitation and perform operation with a sufficient torque margin.

Note 2. Enable the current to be adjusted in consideration of powder deterioration.

24.4 Using as loads for test equipment

Thanks to their good torque controllability, powder clutches/brakes are also used as simulated loads for measuring motor characteristics and for equipment used to test the durability of power transmission elements such as gears and belts.
The following describes selection methods, example selection calculations, and points to be noted when using powder clutches/brakes as loads for test equipment.

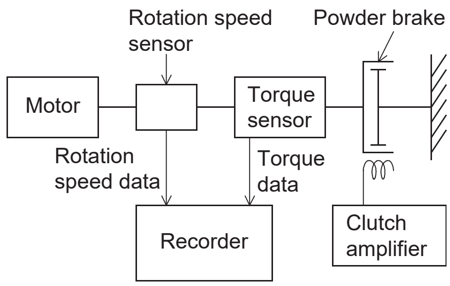
1. Selection method

Selection is basically performed in the same manner as when selecting powder clutches/brakes for tension control. This means that the torque, rotation speed, and heat dissipation (heat generation) must be confirmed to be within the allowable value ranges.
(Be aware that even if powder clutches/brakes are used within the rated torque range and below the allowable rotation speed, they cannot be used unless the heat dissipation (heat generation) is within the allowable continuous heat dissipation range. Refer to “24. Selection procedure for powder clutches/brakes” (page 37) for details.)

2. Selection example for powder clutches/brakes used for test equipment

Performance test equipment for DC motors with reduction gears

Select a powder brake for measuring the characteristics of a motor with a reduction gear that has an output of 600 W (torque: 44 N·m, rotation speed; 130 r/min).
Heat dissipation P is:
P = 0.105 × T × Nr = 0.105 × 44 × 130 = 600 (W)
(As can be seen from the calculation result, motor output = powder brake heat dissipation (heat generation).)
Select the ZKB-5HBN powder brake (allowable continuous heat dissipation: 1,100 W, rated torque: 50 N·m, allowable rotation speed: 1,800 r/min).
Change the load torque applied to the motor by changing the excitation current of the powder brake and record the changes to motor current and rotation speed.

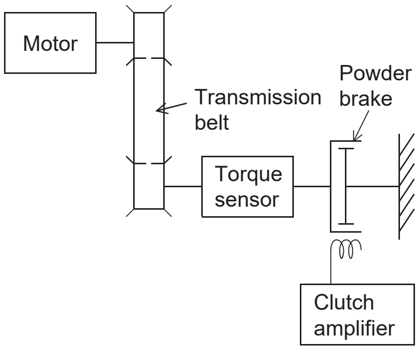


Equipment for testing the durability of transmission belts

Select a powder brake for use on equipment for testing the durability of transmission belts.
As operating conditions, set the load torque to 15 N·m, set the rotation speed to 100 r/min., repeat forward rotation for 10 sec and reverse rotation for 10 sec, and set a stop time of 5 seconds for each time the rotation direction is switched.
Heat dissipation P is:

$$P = 0.105 \times T \times Nr = 0.105 \times 15 \times 100 = 157.5 \text{ (W)}$$

Select ZA-2.5Y1 (rated torque: 25 N·m, allowable rotation speed: 1,800 r/min, allowable continuous heat dissipation: 200 W).



Applying an excitation current to the powder brake even when the rotation is stopped enables the internal powder to be retained on the operating surface, and accelerates the torque build-up time (responsiveness) when restarting.

Note. The torque required for acceleration/deceleration at startup/stopping is actually added to/subtracted from the brake torque and added to the sample.
Added/subtracted torque Ta is calculated by the following formula:

$$Ta = \frac{J \times (N_2 - N_1)}{9.55 \times t} \quad \text{(N·m)}$$

J : Total moment of inertia of rotating parts (kgm^2)
N_1 : Initial rotation speed (r/min)
N_2 : Final rotation speed (r/min)
t : Acceleration/deceleration time (s)

If the effects of acceleration/deceleration torque Ta become a problem, the acceleration/deceleration time t must be increased.

3. Points to be noted when using powder clutches/brakes for test equipment

These are points requiring special attention when powder clutches/brakes are used for load testing.

Torque variations
Although the torque of the powder clutch/brake can be adjusted using electric signals (coil excitation current), because torque is generated by frictional force, torque variations due to variations in the friction coefficient are unavoidable. These torque variations must be taken into consideration when using powder clutches/brakes.
Because the excitation current-torque characteristics shown in sources such as the catalog are typical measurement examples, if current values are set based on these, an error with respect to the target torque will occur. Make sure to measure the torque with a tool such as a torque sensor if accurate torque management is required.

Idling torque
Even if the excitation current is 0 A, a completely unloaded state will be prevented due to the presence of idling torque. (Idling torque is approx. 1 to 4% of the rated torque. Because this will vary depending on the model, refer to the catalog for details.)
To achieve a completely unloaded state, a friction plate type electromagnetic clutch or the like must be used in addition to the powder clutch/brake to perform disengagement mechanically.

Torque responsiveness
Refer to “6. Operation characteristics” (page 7) for the torque responsiveness of powder clutches/brakes. However, when the rotation speed changes, the torque time constant will also change. Also be aware that torque will have the same type of variations.

25. Calculation procedure for selecting a winding clutch input drive motor

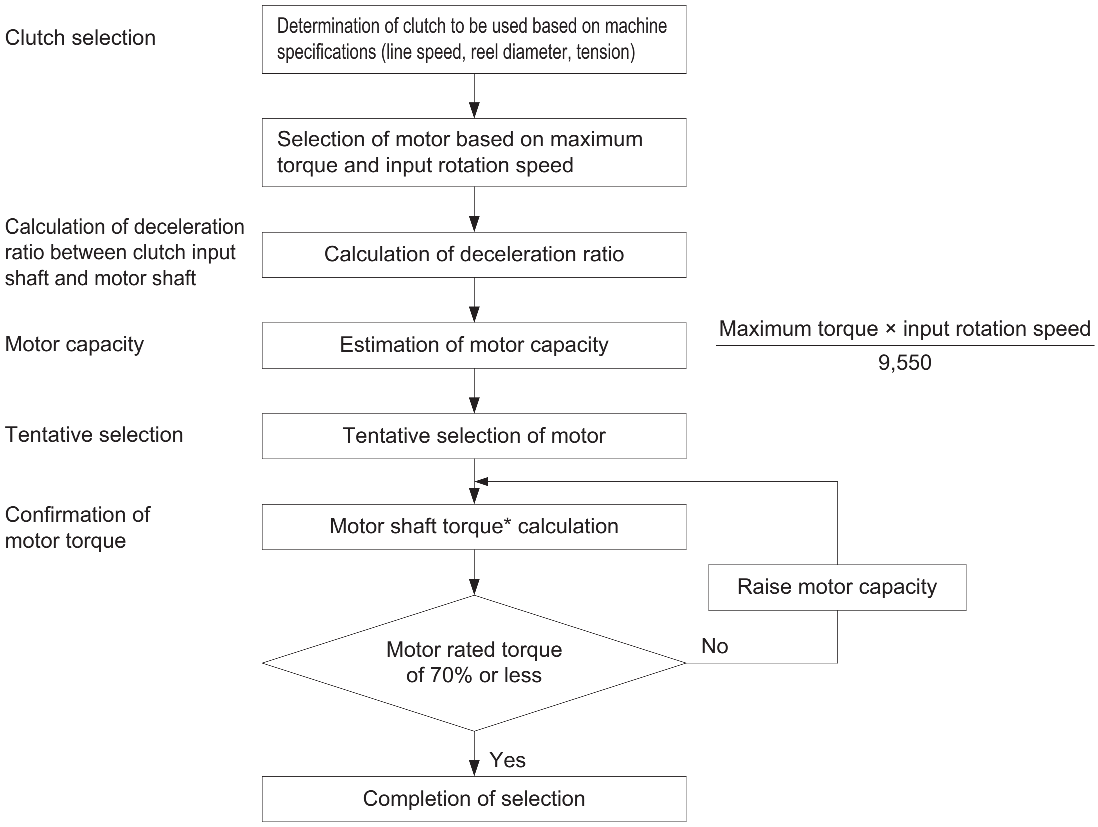
The calculation procedure for selecting a clutch input motor when using a powder clutch on a tension-controlled winding shaft is shown below.

When the clutch input rotation speed is constant

Because the rotation speed of the motor can also be constant when the clutch input rotation speed is constant, a geared motor or general-purpose motor is normally operated using a commercial power supply.

When selecting a motor, make sure to consider the maximum values for clutch input rotation speed and the torque used by the clutch. Also, consider the torque margin for reduction gear efficiency and mechanical loss, and ensure that motor shaft torque is within 70% of the motor rated torque.

Fig. 1 shows the motor selection flow when the clutch input rotation speed is constant.



*Maximum torque of the clutch converted to the motor shaft

Fig. 1 Flowchart for selecting a motor for winding clutch input drive

Selection example

(1) Specifications

Powder clutch used ZKB-0.6AN

Maximum torque used by the powder clutch

T_c: 5.95 N·m

Allowable range for clutch input rotation speed

N_c: 94.2 to 113 r/min

The allowable range for clutch input rotation speed is the rotation speed range that is within the allowable continuous heat dissipation range used when selecting a clutch.

(2) Calculation

(i) Clutch input rotation speed

Clutch input rotation speed

Set the clutch input rotational speed to N_{cin} and determine the value of N_{cin} so that it is within the allowable clutch input rotation speed range N_C.

N_{cin} = 100 (r/min)

(ii) Deceleration ratio between the clutch input shaft and motor shaft

Set the motor rated rotation speed N to 1,500 (r/min). (50 Hz)

The deceleration ratio R between the clutch shaft and motor shaft is:

R = 1,500 ÷ 100 = 15

(iii) Estimating motor capacity

Suppose the estimated motor capacity is P_C,

$$P_C = \frac{T_C \times N_{cin}}{9{,}550} = \frac{5.95 \times 100}{9{,}550} = 0.06 \quad \text{(kW)}$$

Thus, tentatively select a motor with a motor rated output P of 0.1 (kW).

(iv) Confirming motor torque

Suppose the motor rated torque is T_m,

$$T_m = 9{,}550 \times \frac{P}{N} = 9{,}550 \times \frac{0.1}{1{,}500} = 0.63 \quad \text{(N·m)}$$

Suppose the motor shaft torque (maximum torque of the clutch converted to the motor shaft) is T_r,

$T_r = T_C \div R$ = 5.95 ÷ 15 = 0.4 (N·m)

Relative to the motor rated torque Tm, motor shaft torque Tr is:

$$\frac{T_r}{T_m} \times 100 = \frac{0.4}{0.63} \times 100 = 64 \quad (\%)$$

The motor shaft torque Tr is within 70% of the motor rated torque Tm.

Based on the above, select a motor of 0.1 kW 1/15.

Model name (example)

- Geared motor GM-S 0.1 kW 1/15
- General-purpose motor SF-JR 0.1 kW (external gear: 1/15)

Note. Although the slip rotation speed will be higher and controllability will be better the higher the clutch input rotation speed, the heat dissipation (heat generation) will also increase accordingly.

If performing constant slip control

Performing constant slip control reduces the amount of heat generated by the clutch by changing the clutch input rotation speed according to the rotation speed of the clutch output shaft to keep the slip rotation speed constant.

Because the rotation speed of the clutch output shaft normally decreases as the winding of the winding shaft becomes thicker, if the clutch input rotation speed is constant, the slip rotation speed will gradually increase and heat generation during operation will increase.

Items necessary to perform constant slip control

- Inverter (capable of constant torque operation), etc. (to make motor rotation speeds variable)
- Constant torque motor
  A low rotation speed and high torque are required when the winding of the winding shaft becomes thicker.
  Thus, select a constant torque motor capable of high torque input even at low rotation speeds. There is a high possibility that torque will be insufficient at low rotation speeds if a general-purpose motor is used.

When selecting a motor, make sure to consider the maximum value for the clutch input rotation speed range and the torque used by the clutch. Also, consider the torque margin for reduction gear efficiency and mechanical loss, and ensure that motor shaft torque is within 70% of the motor rated torque.

Select a motor rotation speed that is within the range where constant torque operation is possible (e.g., 90 to 1,800 r/min, 3 to 60 Hz).

Note. The range of rotation speeds at which operation with constant torque is possible will also vary depending on the motor and inverter control method used. Check the motor and inverter specifications for details.

Fig. 2 shows the motor selection flow when a powder clutch is used for constant slip control.

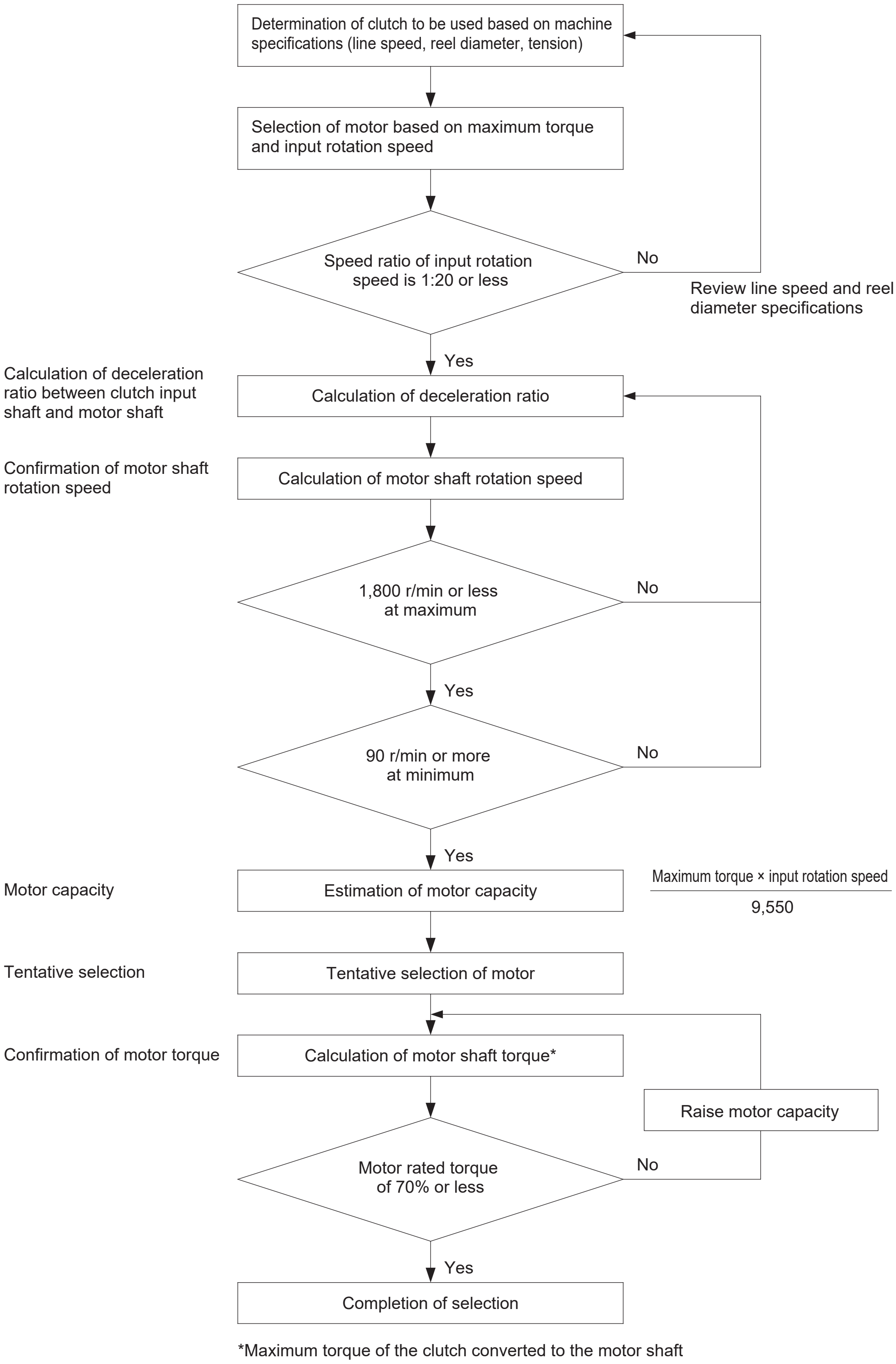


Fig. 2 Flowchart for selecting a motor for constant slip winding

Example of selection calculation

(1) Specifications

Powder clutch used ZKB-1.2BN

Maximum torque used by the powder clutch

Tc: 10.7 N·m

Clutch output shaft rotation speed

Ncout: 83.6 to 1,592 r/min

Allowable slip rotation speed range

Ns: 5 to 97 r/min

The allowable range for slip input rotation speed is the rotation speed range that is within the allowable continuous heat dissipation range used when selecting a clutch.

(2) Calculation

(i) Slip rotation speed
With N_{ss} as the slip rotation speed is used, determine the value so that the slip rotation speed is within the allowable range N_s.
N_{ss} = 30 (r/min)

(ii) Clutch input shaft rotation speed
If N_{cin} is the clutch input rotation speed:
$N_{cin} = N_{cout} + N_{ss}$ = (83.6 to 1,592) + 30
= 113.6 to 1,622 (r/min)

If the speed ratio of N_{cin} is 1:20 or more, the range of the clutch output shaft rotation speed N_{cout} is wide and exceeds the inverter speed control range, meaning it is necessary to review the conditions for line speed and reel diameter.

(iii) Deceleration ratio between the clutch input shaft and motor shaft
Set the motor rated rotation speed N to 1,800 (r/min).
The deceleration ratio R between the clutch shaft and motor shaft is:

$$R = \frac{N}{N_{cin}\,(MAX)} = \frac{1{,}800}{1{,}622} = 1.10974\ldots \rightarrow 1$$

(iv) Estimating motor capacity
Suppose the estimated motor capacity is P_c,

$$P_c = \frac{T_c \times N_{cin}\,(MAX)}{9{,}550} = \frac{10.7 \times 1{,}622}{9{,}550} = 1.82 \quad (kW)$$

Thus, tentatively select a motor with a motor rated output P of 2.2 (kW).

(v) Confirming motor torque
Suppose the motor rated torque is T_m,

$$T_m = 9{,}550 \times \frac{P}{N} = 9{,}550 \times \frac{2.2}{1{,}800} = 11.6 \qquad (N \cdot m)$$

Suppose the motor shaft torque (maximum torque of the clutch converted to the motor shaft) is Tr,
Tr = Tc ÷ R = 10.7 ÷ 1 = 10.7 (N·m)
Relative to the motor rated torque Tm, motor shaft torque Tr is:

$$\frac{T_r}{T_m} \times 100 = \frac{10.7}{11.6} \times 100 = 92.3 \qquad (\%)$$

Because the motor shaft torque Tr exceeds 70% of the motor rated torque Tm, increase the motor capacity in consideration of speed reducer efficiency and mechanical loss.

Tentatively select a motor with a motor rated output P of 3.7 (kW).

(vi) Confirming motor torque
Suppose the motor rated torque is Tm2,

$$T_m2 = 9{,}550 \times \frac{P}{N} = 9{,}550 \times \frac{3.7}{1{,}800} = 19.6 \qquad (N \cdot m)$$

Relative to the motor rated torque Tm2, motor shaft torque Tr is:

$$\frac{T_r}{T_m2} \times 100 = \frac{10.7}{19.6} \times 100 = 54.6 \qquad (\%)$$

The motor shaft torque Tr is within 70% of the motor rated torque Tm2.

(vii) Confirming motor shaft rotation speed
Suppose the motor shaft rotation speed is N_m,
$N_m = N_{cin} \times R$ = (113.6 to 1,622) × 1
= 113.6 to 1,622 (r/min)
Because the motor shaft rotation speed Nm is within the range of 90 to 1,800 r/min, it is within a range in which constant torque operation is possible.

Based on the above, select a direct-connection motor of 3.7 kW.

Model name (example)
Constant torque motor SF-PR-SC3K4P (for direct connection to clutch input shaft)
Inverter FR-A820-3.7K

Note. Although controllability will be better at higher slip rotation speeds, heat dissipation (heat generation) will also increase accordingly.

26. Selection format

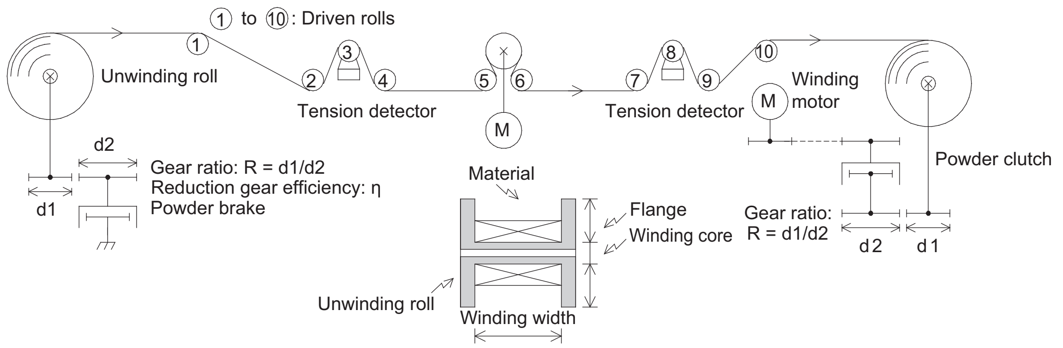
The most basic selection format is shown below.
Please use it for making selection calculations.

26.1 Powder clutch/brake specification contact sheet

● For unwinding/winding Note: Circle either one.

Customer name		Machine name		Delivery		Quantity	

Configuration



Please fill the items indicated with * without fail.

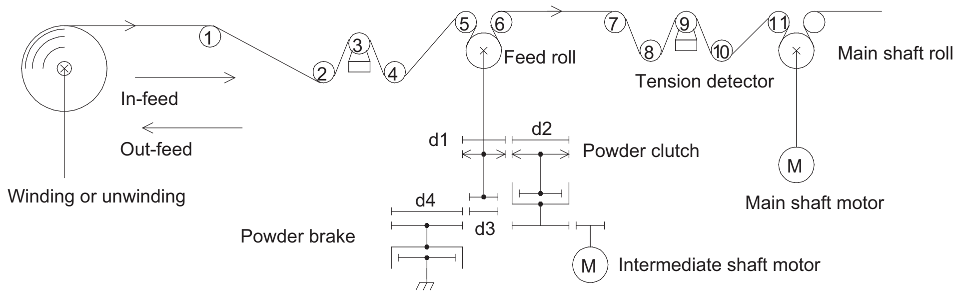
Operational tension *	Minimum Fmin = ______ N Maximum Fmax = ______ N
Reel diameter *	Minimum Dmin = ______ m Maximum Dmax = ______ m
Line speed *	Minimum Vmin = ______ m/min Maximum Vmax = ______ m/min
Acceleration/ deceleration time	Maximum Tmin = ______ s (0→Vmax, Vmax→0)
Reel mass	Weight of material Wm = ______ kg Weight of reel core Wc = ______ kg Weight of flange Wf = ______ kg Winding width Lm = ______ mm
Operation cycle	Time required to complete one roll ______ min Interval ______ min
Material	Type ______ Width ______ mm Thickness ______ μm
Environmental condition	Temperature ______ °C Humidity ______ % Vibration ______ m/s² Explosion proof requirement ______
Forced cooling method	Air source Yes/No Water Yes/No
Method of control	(A) Manual (B) Open-loop control (C) Feedback control
Type of control	(A) Constant tension (B) Taper ratio (Minimum:)% (Maximum:)%
Turret	(A) Yes (B) No
Auto paster	(A) Yes (B) No
Reel diameter detector	(A) Required (B) Not required (For external taper control)

Note 1. Attach a power system diagram if one is available.
Note 2. If the inertia of the driven roll has a large effect, enter the weight in the blank.

- For intermediate shaft

Customer name		Machine name		Delivery		Quantity	

Configuration



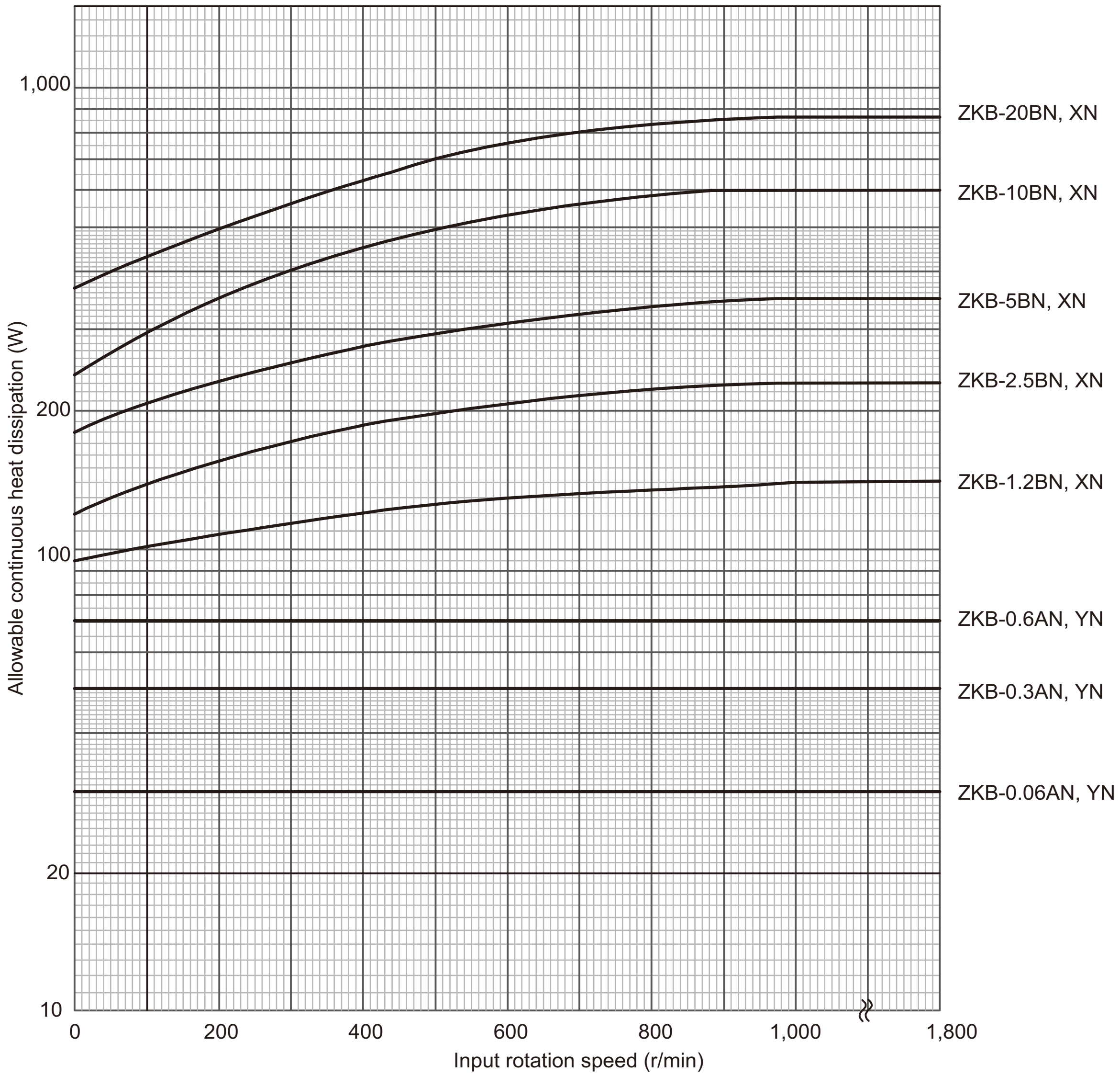
Please fill the items indicated with * without fail.

Operational tension *	Inside F_{1min} = ________ N (On the side of roll (6) for out-feed); F_{1max} = ________ N (On the side of roll (5) for in-feed) Outside F_{2min} = ________ N (On the side of roll (5) for out-feed); F_{2max} = ________ N (On the side of roll (6) for in-feed)
Feed roll *	Feed roll diameter Do ________ m
Line speed *	Minimum V_{min} = ________ m/min Maximum V_{max} = ________ m/min
Acceleration/ deceleration time	Minimum T_{min} = ________ sec ($0 \rightarrow V_{max}$, $V_{max} \rightarrow 0$)
Mass of feed roll	W_d = ________ kg
Operation cycle	Time required to complete one roll ________ min Interval ________ min
Material	Type ________ Width ________ mm Thickness ________ μm
Environmental condition	Temperature ________ ℃ Humidity ________ % Vibration ________ m/s² Explosion proof requirement ________
Forced cooling method	Air source: Yes/No Water: Yes/No
Type of control	(A) Manual (B) Open-loop control (C) Feedback control
Others	Set the efficiency of the reduction gears (d_1/d_2, d_3/d_4) to be η=0.9 to 1 and consider the mechanical loss torque of each roll to be negligible.

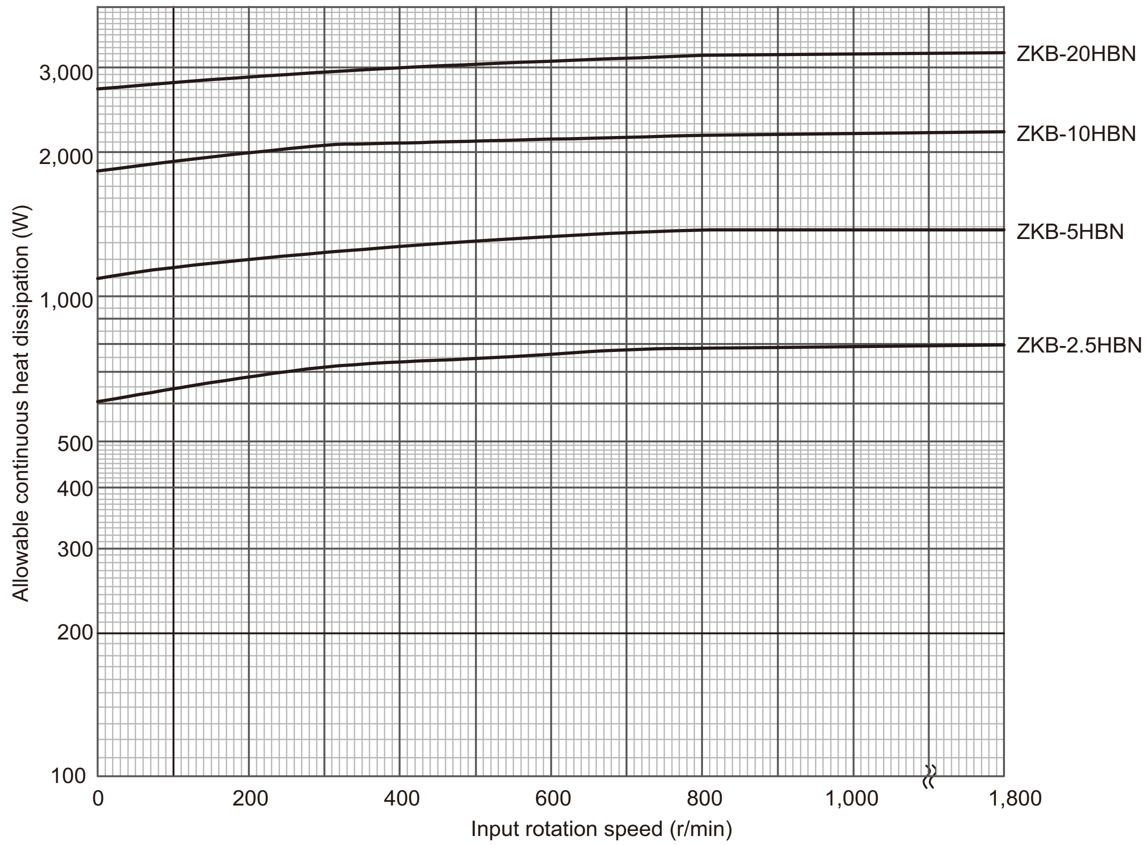
Find the clutch/brake models and gear ratio d_1/d_2 and d_3/d_4 based on the basic specifications above. However, the input rotation speed of clutch shall be set so that the rotation speed of the feed roll is 10% higher than that of the main shaft roll when the clutch is fully engaged.
In addition, the bias torque, equivalent to 10% of the maximum tension, shall be applied to the clutch/brake, and the minimum slip rotation speed of the clutch shall be higher than the minimum operational rotation speed of the clutch.
When the tension on the feeding side is constantly higher than that of the discharging side, no brake is required. On the contrary, when the tension on the feeding side is constantly lower than that of the discharging side, no clutch is required. However, when the difference between the feeding side tension and discharging side tension is small and the torque based on the difference above is smaller than the minimum control torque of the clutch and brake, both clutch and brake shall be used in combination.

Note 1. Attach a power system diagram if one is available.
Note 2. If the inertia of the driven roll has a large effect, enter the weight in the blank.

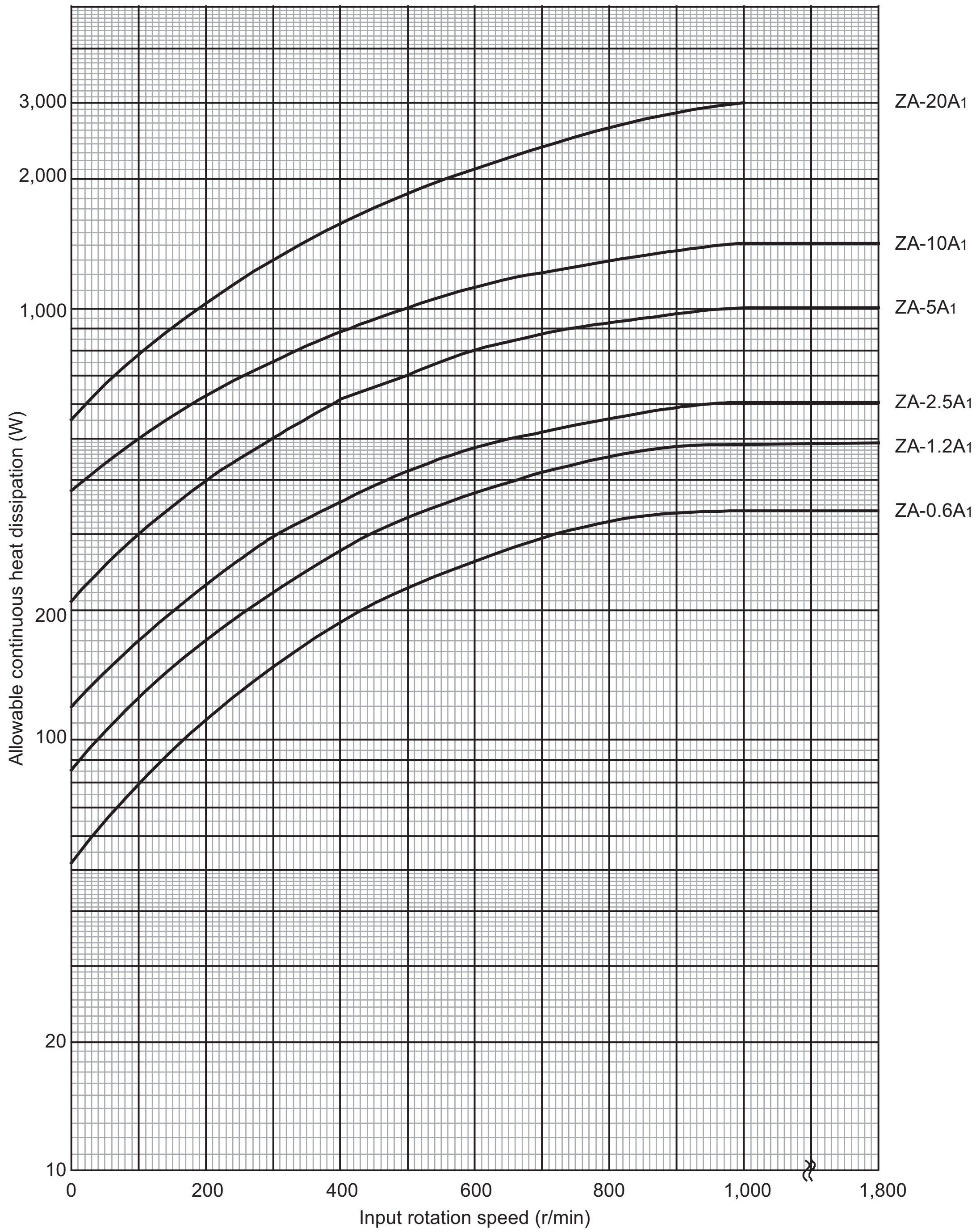
27. Allowable continuous heat dissipation



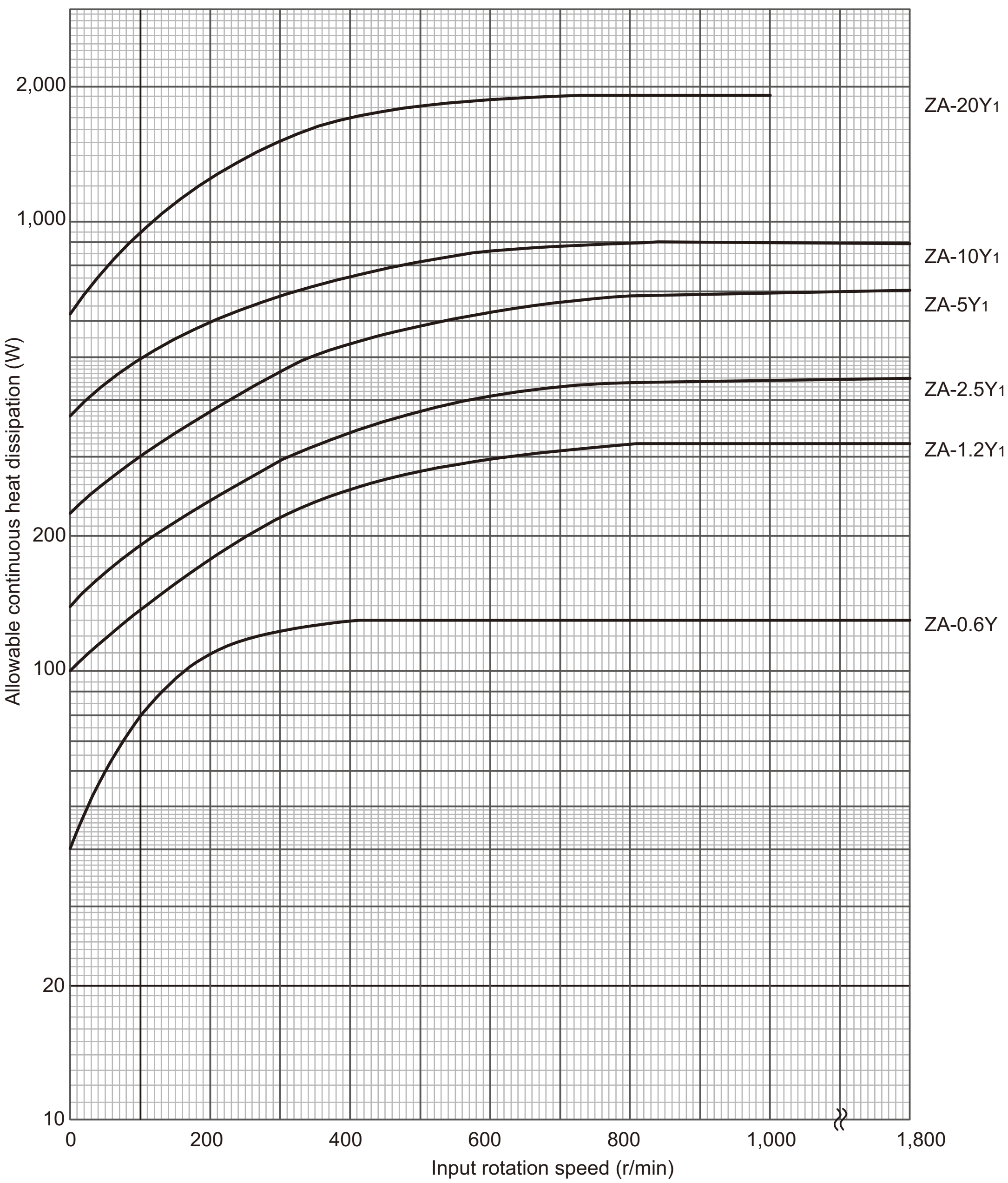
ZKB-AN, BN, XN, and YN powder clutches/brakes



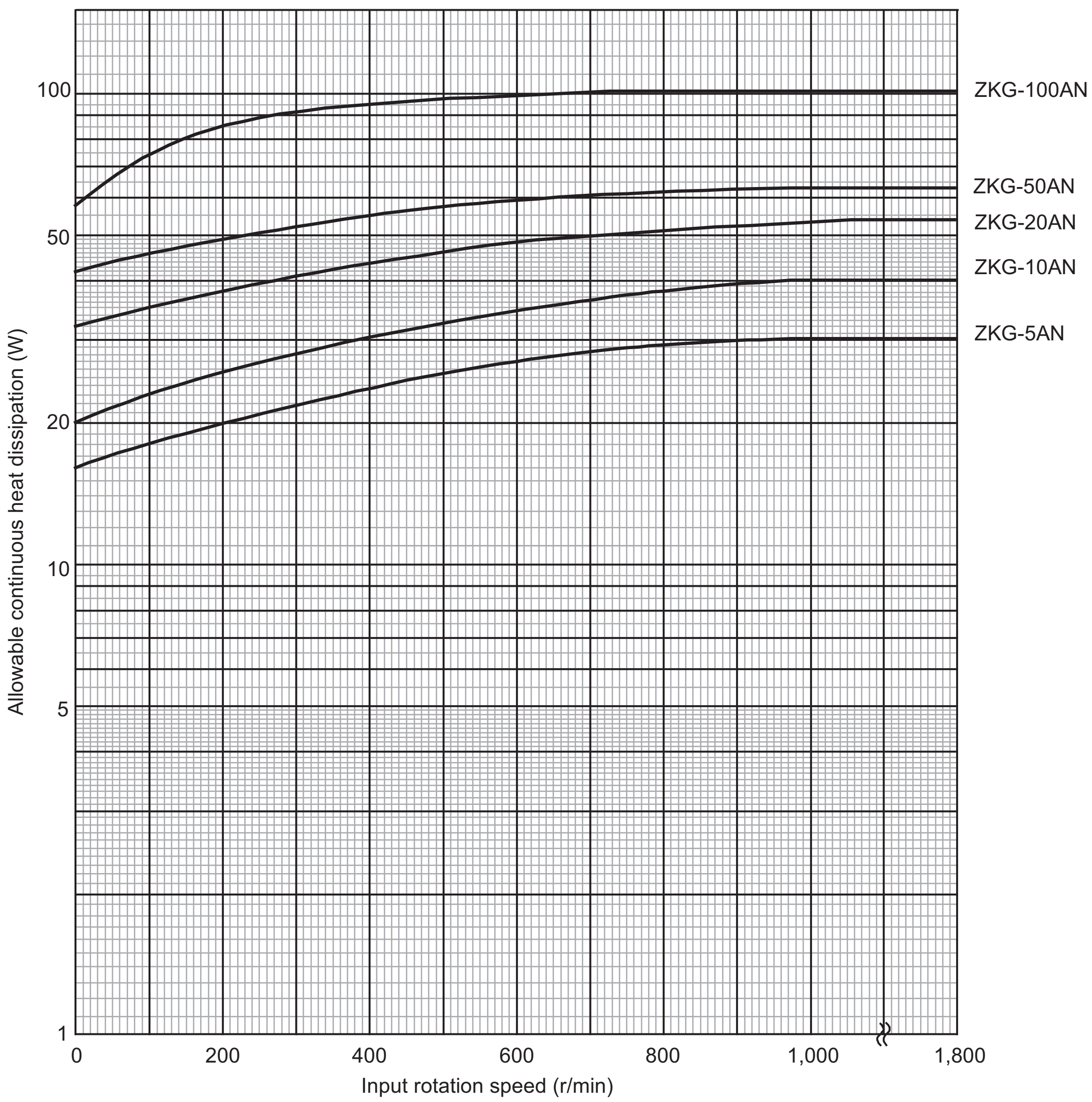
ZKB-HBN powder brake



ZA-A1 powder clutch



ZA-Y powder brake



ZKG-AN micro powder clutch

28. Usage precautions

28.1 General items

1. Do not mount the input shaft and the output shaft reversely. For the powder clutch, the normal mounting method is to use the high-speed rotation side as the input side. (For the ZA type, the hollow shaft is on the output side, and for the ZKB type, the input/output shafts are indicated by the arrows on the external dimension drawing of this catalog and on the name plate.) Usage with the input and output mounted reversely in continuous idling is not recommended in view of the torque characteristics and powder lifespan.
   In addition, in principle, the clutch/brake should be used on a horizontal shaft; they cannot be used on a vertical shaft.
2. Be careful when installing a pulley, coupling, or shaft. When fitting a pulley, coupling, or shaft to the product, be sure to use clearance fit and not to apply excessive force to the product. Applying impacts, etc., to the product may scratch the inside bearings and quickly cause damage.
3. Be careful of powder wetness. The performance becomes unstable if the powder becomes wet, so take great care not to allow water, oil etc., to enter inside. Especially, when installing the product close to the gearbox, oil may flow in through the shaft, so seal the shaft completely. In addition, the product is not hermetically sealed, so it cannot be used in environments where oil mist, oil, or water is directly applied. Also, be aware that condensation may cause powder wetness, which affects product characteristics unfavorably.
4. Be careful that the surface temperature does not exceed the limit temperature. Control the maximum surface temperature by continuous operation under the conditions shown in the table below. Exceeding this value will greatly reduce the durability.

Limit of powder clutch/brake surface temperature (stator circumference)

Model	Limit temperature (approximate)
Natural cooling Thermoblock	100°C or lower
Forced air cooling	70°C or lower

However, this is based on an ambient temperature of 30°C.

The above-described limit temperatures are approximate values. Be sure to use the clutch within the allowable continuous heat dissipation.

28.2 Relationship between rated torque and rated current

1. Torque significantly exceeds the rated torque when the rated current is applied at the time of shipment (after running in) (refer to the standard torque characteristics for each model).
   Because the torque is set to be high in anticipation of aging deterioration of the powder, use the product by slightly reducing the current so that the rated torque is not exceeded.
2. Although torque reduction occurs due to aging deterioration, stable torque transmission is possible because torque will also be increased as current is increased. However, use a current that does not cause rated values to be exceeded.

28.3 Torque

1. For the current vs. torque characteristics, the standard values of new products at 200 r/min are listed. As the powder deteriorates over time, this standard characteristic will change. Correct the change in torque characteristics with current.
2. Torque can be easily controlled by current, but note that torque may become unstable, especially when using large models (torque of 100 N·m or more) at high-speed rotation and at low current.
3. Note that when ON/OFF control is performed at high-speed rotation, it may take a considerable amount of time to reach the predetermined torque.
4. Torque variation near the rated current is approx. ±10% for each product. The variation between products is approx. ±15% of the standard torque characteristic. Therefore, when clutches and brakes are operated in parallel, it is recommended to design so that current can be individually adjusted.
5. The torque value shows hysteresis. Therefore, please be aware that an increase or decrease of the current will cause a difference in torque.

28.4 Lifespan

1. When the product is used in continuous slip for winding or unwinding, the lifespan of the powder varies depending on the usage conditions (relative slip speed, etc.), but in general, when it is used at the allowable continuous heat dissipation, the life of the powder, where the torque drops to the rated torque at the rated current, is approx. 5,000 to 8,000 hours. However, if it is used at the rated torque or lower, it can be used continuously, so the lifespan will be extended. However, even at the same heat dissipation, when the slip rotation speed, that is, the relative rotation speed, is continuously at a relatively high level, the lifespan time tends to be short, so make settings so that the relative rotation speed is as low as possible.
2. Using the product with allowance for allowable continuous heat dissipation can extend the lifespan of the powder. For example, if the product is used at 50% of the allowable continuous heat dissipation, the lifespan may be approx. twice or more.

28.5 When operating at low speed (15 r/min or less)

When using the product in continuous operation such as tension control, it shows stable torque characteristics, but in intermittent operation involving idle rotation, the build-up of torque may be slightly delayed immediately after voltage application. To avoid this, use the product as follows.

1. Even after completion of unwinding, keep applying weak excitation (5 to 10% of rated current) so that the powder does not fall off from the operating surface (refer to “3. Using weak excitation currents” (page 77) in the Q&A for information regarding weak excitation).
2. Increase the speed so that the minimum rotation speed becomes 15 r/min or higher. However, be aware that accurate torque control may not be possible due to mechanical loss, etc., of the acceleration mechanism if the acceleration ratio is large.
3. The ZKB, ZKG, and ZX series can be used from approx. 5 r/min.

28.6 Performing run-in operation

1. Since the powder inside the powder clutch/brake is unevenly distributed due to shock during transportation, running in must be performed before starting regular operation (for the running in procedure, refer to “9. Running in” (page 11) or the instruction manual).
2. In some cases, the uneven distribution of powder may cause the shaft to rotate slowly, lock up, or generate abnormal noise. If this happens, use a rubber mallet to lightly apply impact to the outer circumference of the clutch/brake. Any of these can be resolved by performing operation.

28.7 For forced air cooling

1. Install an air filter. Compressed air used as cooling air contains oil and moisture, so be sure to use clean dry air passed through an air filter (complete oil removal type).
   (If compressed air not passed through an air filter is used, the powder becomes moist due to moisture and oil content and the performance drops sharply.)
2. If the piping is long and it is branch piping, check if the air flow rate near the clutch/brake suction pipe is more than the specified amount.

28.8 Thermoblock cooling type

1. An axial flow fan (blower) is provided. If the performance of this axial fan decreases, heat dissipation will be worse and the allowable continuous heat dissipation rate will be reduced, so install the fan with a clearance around it. Especially when the surrounding environment is bad and there is a possibility of foreign matter adhering to the guard of the axial fan, clean it periodically.
2. Since a thermal switch for detecting the temperature is provided on the side of the stator, be sure to connect it to an alarm device for alarm detection.

28.9 Selection

1. Even within the allowable continuous heat dissipation, products cannot be used exceeding the rated torque.
2. When the control range of tension is wide, multiple clutches may be installed and switched over during operation. In this case, use an electromagnetic clutch to disconnect the unused clutch to prevent the output side from being forcibly idled.
3. A gear ratio of 5 or less is recommended. When the gear ratio is too large, control may be unstable due to the influence of mechanical loss.

28.10 Abnormal torque at startup

1. Depending on the operation pattern (turning on the coil current at rotation stop and applying rotation to the input shaft, or starting rotation at the same time as turning on the coil current), a temporarily higher torque (peak torque) than specified may be generated at startup. Especially when vibration is added while the current is off, powder tends to be unevenly distributed, so this tendency appears remarkably. To counter this problem, keep supplying weak excitation current to the coil of the clutch/brake even while it is stopped. This makes the problem less likely to occur.
2. Peak torque may occur similarly when the powder is wet. In this case, however, the product may need to be replaced.

28.11 Others

1. Note that at high altitude the allowable continuous heat dissipation will be lowered due to atmospheric pressure. This specification applies to an altitude of 1,000 m or less.
2. The protection degree is IP00. Therefore, the powder clutch itself may emit oxidized powder or fine powder, so it cannot be used where dust is completely prohibited.
3. The powder clutch/brake does not generate coupling noise or braking noise, unlike friction plate type clutches/brakes. However, it generates friction sound because torque is generated by the frictional force of powder connected by electromagnetic force. Normally, the friction sound is of a level that is not a problem in ordinary machines, but it may become large due to the influence of internal powder distribution (usually, the sound will be reduced after running in for some time).
4. There is no problem at the vibration levels of general printing machines, paper machines, packaging machines, etc., without abnormal vibration, but it cannot be used on machines with impact force.
5. When a voltage is applied to the clutch/brake, a magnetic flux is generated, and the installation shaft, etc., are magnetized by this flux. If this magnetization becomes a problem, installation with nonmagnetic materials is recommended, but it cannot be completely eliminated. Note that the protruding shafts of models such as the ZKB are also magnetized.

Q&A

Q&A

1. Performance

Q1 How significant is torque variation (for one product and between products)?

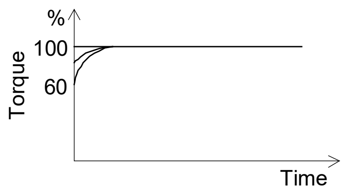
A Torque variation (when near the rated current) is approximately ±10% for one product and ±15% between products.

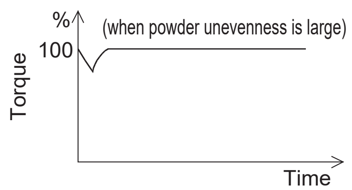
Q2 What is the torque control range of a powder clutch? Are the ranges different for manual control and automatic control?

A
- Manual control, reel diameter detection type tension controller
  It is recommended to use it at 5 to 100% of rated torque, which excels in linearity of the excitation current-torque characteristics.
  Although usage is possible at less than 5%, controllability will be poor.
- Tension feedback type automatic control
  Usage is possible in the range between the idling torque and rated torque of the product.
  Although normally the idling torque is approximately 2% of the rated torque, because idling torque will vary depending on the model, please refer to the specifications in the catalog.

Q3 What happens to torque when slip rotation is applied in a statically engaged state?

A At the start of slip, the torque generated is 60 to 100% of the normal (post running in) torque due to the powder distribution before excitation (engagement) when static. After startup, the slip causes the powder distribution to improve and approach the normal torque as shown in the figure below.





Peak torque (sticking) may occur at startup if the powder is unevenly distributed due to causes such as idling when excitation is shut off or if the powder is damp.

In such cases, eliminate the problem by applying weak excitation or by turning on excitation after the clutch/brake has rotated.

Q4 Is it possible to transmit torque even when there is zero slip?

A This is the same as for the static engagement mentioned in Q3.
Although torque may be transmitted, the coupling force will be 60 to 100% of the specified torque (normal torque). When this occurs, any slip will cause the torque to near the specified torque.

Q5 Is it possible to determine the torque from the standard torque characteristics in the catalog by using it for measuring motor torque and measuring the clutch current?

A Because a torque variation will exist between products, use the standard torque characteristics as a guideline. Obtain precise measurements by using a torque meter or spring scale, etc.

Q6 If running in is performed when the machine is manufactured, is it necessary to perform running in again after installation?

A Running in must be performed again after installation to alleviate any powder unevenness caused by vibrations during machine transport.

Q7 When using a powder clutch for winding, why is winding not possible at the same position as the clutch amplifier?

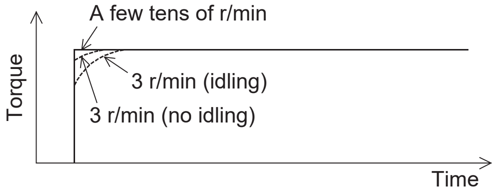
A This is due to powder deterioration. Although correction is possible by increasing the voltage, if winding is not possible even when 24 V DC is applied, the powder can be considered to be at the end of its lifespan.

2. Usage at low rotation speeds

Q1 What will happen if used at low rotation speeds?

A At an extremely low rotation speed, such as approx. 3 r/min (assuming that running in has been completed), the time necessary for torque build-up will be as shown in the figure to the right. Because powder cannot be distributed with the centrifugal force generated at low rotation speeds, some powder will fall from the operating surface when stopped with no excitation. This results in a phenomenon in which some time is necessary before the powder can be evenly distributed again.
Furthermore, the powder falling from the operating surface when stopped with no excitation may cause an increase in torque variation during regular operation. This phenomenon can be eliminated (or alleviated) by applying weak excitation when stopped.

Conceptual diagram (without weak excitation current)



3. Using weak excitation currents

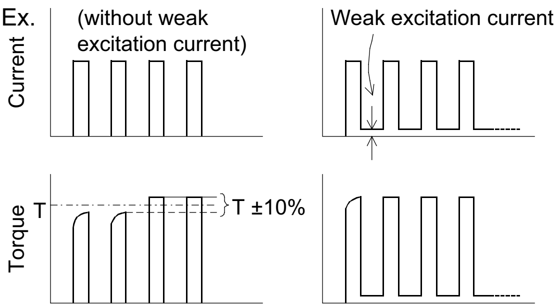
Q1 What is “weak excitation current”?

A Weak excitation generally means exciting at approx. 5 to 10% of the rated current while the clutch/brake is stopped or idling. (Because larger weak excitation currents will result in more stability, exciting at more than 10% within the range allowed for actual machine operation will not create a problem.)

Q2 What are the advantages of using while applying weak excitation?

A Applying weak excitation after running in has been performed enables powder to be consistently held on the operating surface, which in turn has the following advantages:
- Torque reproducibility is significantly enhanced.
- Torque sticking during start-up is eliminated.
- Torque build-up is accelerated, even at low rotation speeds.

Ex.



Q3 Is weak excitation necessary for all of these?

A Normally, weak excitation is unnecessary, except in the following cases.
- When preventing torque sticking during start-up when the shaft idles or when there is impact during operation.
- When torque reproducibility is of particular importance.
- Under usage conditions in which proper powder distribution is difficult, such as when operating at extremely low speeds or when using while revolving.

4. Maintenance

Q1 What materials is the powder made of?

A Although the powder is made from a type of stainless steel, in the case of powder clutches, the type used has an especially high magnetic permeability and low residual magnetism, as well as high thermal resistance and wear resistance. Its size is approx. 50 μm.

Q2 How is powder lifespan (overhaul timing) determined?

A When used for long periods, the powder suffers oxidization and wear, causing the generated torque to decrease. As it oxidizes, its color changes as follows: gray -> black gray -> black brown -> dark brown -> reddish brown. As a guideline, consider the powder's life to span until the torque is decreased by 30% or more from its initial state.
If torque measurement proves difficult, make a judgment by considering "the finished state of the product" or whether "torque is insufficient even when volume is increased fully".

Q3 What is the approximate powder lifespan (overhaul timing)?

A Although powder lifespan will vary significantly depending on the usage conditions, it will be at least 5,000 to 8,000 hours, and up to 15 years without maintenance in some cases.

Q4 Can ZKG models be repaired?

A Product replacement is necessary (ZX models can also not be repaired).

5. Coils and current

Q1 Do the coils have positive (+) and negative (-) polarities?

A Although DC voltage is applied to powder clutches/brakes, they have no polarity.

Q2 Does starting current flow to the coils?

A In principle, the starting current does not flow as in the case of a motor.

Q3 How many amperes will flow when 12 V DC is applied at a room temperature of 20°C? And how about at 40°C?

A Coil temperature and resistance have the following relationship:

$$\frac{R1}{234.5 + t1} = \frac{R2}{234.5 + t2}$$

R1Ω is the resistance when the temperature is t1°C
R2Ω is the resistance when the temperature is t2°C

Therefore, resistance Rx and current Ix at temperature tx are:

$$Rx\ (\Omega) = \frac{234.5 + tx}{234.5 + t1} \times R1$$

$$Ix\ (A) = \frac{E}{Rx}$$ E: Applied voltage (V)

[with ZKG-10YN used as a reference example]

(From the catalog)

At 75°C, the coil resistance is: $\frac{24\ (V)}{0.42\ (A)} = 57\Omega$

At 20°C:

$$R20 = \frac{234.5 + 20}{234.5 + 75} \times 57 = 46.9\ (\Omega)$$

$$I20 = \frac{12}{46.9} = \boxed{0.26\ (A)}$$

Similarly, at 40°C:

$$I40 = \boxed{0.24\ A}$$

However, because the coil temperature starts to rise immediately due to heat generated by energization and slipping, the current will drop in the case of a constant voltage power supply.
The catalog shows current values when 24 V DC is applied at a coil temperature 75°C.
The current at 20°C is 1.22x this.

6. Mounting

Q1 Is the shaft difficult to turn by hand after being installed to the machine? Also, the variation between products is large. Why is that?

A It feels heavy because the powder is unevenly distributed before the running in and because the shaft with a small shaft diameter is turned.
Also, variation will be large because of variations in the degree of unevenness.
Check again after performing running in (seals will also become acclimatized, which will make it lighter).

Q2 Can the powder clutch be vertically mounted on the shaft?

A This is not possible because it prevents the uniform distribution of powder.

Q3 Use of an elastic coupling is not possible. To what degree should centering be performed?

A Use an eccentricity of 0.04 mm or less.

Q4 Can the input and output be mounted reversely?

A Although this is possible, we do not recommend it in consideration of durability and torque stability.
Also, in this case, the input rotation speed in the allowable continuous heat dissipation diagram shown in the catalog is the output rotation speed.

Q5 Why can impacts not be applied?

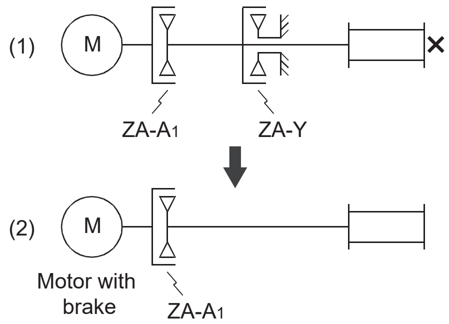
A Doing so would impair the uniform distribution of powder.
It would accelerate bearing breakage.

Q6 Is it alright to use just one side of the mounting plate for ZKB-20BN?

A For rigidity, mount models ZKB-5BN and above on both sides.

Q7 Should ZA-A1 and ZA-Y models be attached to a single shaft with a rewinder (for winding and unwinding)?

A To avoid any adverse effects from idling, use the ZA-A1 clutch as shown in figure (2) below, and use both a winding clutch and an unwinding brake.



Q8 Is it possible to use the ZKB-10BN as a brake instead of the ZKB-10XN?

A Such usage is possible providing the output side is fixed.

Q9 What will happen if the fan of the ZKB-HBN is mounted in reverse?

A Such usage is not possible because it will result in a significantly decreased allowable continuous heat dissipation.

7. Cooling

Q1 What is the relationship between the heat dissipation and coil loss (power consumption) of the ZKG model?

A Except in cases when overexcitation control is performed for applications such as high-frequency starts/stops, only the heat dissipation needs to be selected, with no consideration necessary for power consumption (coil loss).

Q2 What is the allowable surface temperature for powder clutches/brakes?

A Surface temperatures during continuous operation should be limited to those shown in the table below. Exceeding these values will greatly reduce the durability.

Limit of powder clutch/brake surface temperature (stator circumference)

Model	Limit temperature (approximate)
Natural cooling Thermoblock	100°C or lower
Forced air cooling	70°C or lower

However, this is based on an ambient temperature of 30°C.
The above-described limit temperatures are approximate values. Be sure to use the clutch within the allowable continuous heat dissipation.

Q3 Is usage possible with the natural cooling type when the ambient temperature is 100°C?

A Such usage is not possible because the allowable surface temperature is 100°C and because it is clear that the surface temperature will exceed the ambient temperature (100°C) due to the heat generated during use.
Please use within a range of 0 to 40°C.
If the ambient temperature exceeds 40°C, derate the allowable continuous heat dissipation as follows:

$$Pt = \frac{T - t}{T - 40} \times P$$

Pt : Allowable continuous heat dissipation (W) when the ambient temperature is t°C
t : Ambient temperature (°C)
T : Allowable surface temperature of clutch (°C)
P : Allowable continuous heat dissipation (W)

8. Environmental considerations

Q1 Is outdoor usage possible?

A In principle, such usage is not possible because powder clutches/brakes are manufactured based on the assumption that they will be used in a factory setting.
In the event they are used outdoors, an environment similar to that indoors must be created by installing a cover in locations where they may be subjected to contact with water, oil, dust, briny air, etc. Measures must also be taken to prevent condensation.

Q2 Can clutches/brakes be subjected to tropical treatment?

A No special treatment is necessary for clutch/brake units.
However, humidity countermeasures must be taken without fail.
(See “21. Packaging procedure at the time of export” (page 33).)

Q3 Is usage in a vacuum possible?

A Such usage is not possible because it will result in a significantly decreased allowable continuous heat dissipation due to the fact that slip heat cannot be dissipated into the atmosphere.

Q4 In what temperature/humidity ranges can powder clutches/brakes be used?

A They can be used in an ambient temperature of 0 to 40°C and in a relative humidity of 30 to 90%, similar to that of a general factory atmosphere. However, if this humidity is exceeded and there are concerns regarding condensation, the clutch/brake temperature is to be kept higher than the surroundings by means such as continuous energization.

Q5 Is usage in a refrigerated warehouse (-30°C) possible?

A Although operation as a clutch/brake is possible even in low-temperature environments, the intrinsic performance cannot be guaranteed due to problems such as large bearing loss torque or limited control ranges.

Q6 Is usage in cleanrooms possible?

A Such usage is generally not possible because the clutch/brake is not a completely sealed structure and there is a risk that the fine powder generated by usage may leak. Because dust is generally generated from other moving parts such as gears and belts even when the clutch/brake is covered with a cover, it is recommended to cover all moving parts before use.

9. Selection

Q1 Is it possible to increase the line speed from 50 m/min to 80 m/min with my existing machine?

A If the tension (F) and winding diameter (D) are not changed, confirm that the allowable continuous heat dissipation and allowable rotation speed are not exceeded.
If F or D change, also confirm that the torque usage range is appropriate.

Q2 What is the upper limit for torque usage of powder clutches?

A Although powder clutches are designed so that their torque is higher than the rated torque at the time of shipment from the factory in anticipation of deterioration over time, the rated torque is the upper limit. Usage above this limit is not covered by warranty.

10. Clutch amplifiers

Q1 What is the protective element used for?

A A reverse voltage is generated on both sides of the coil when the DC excitation current is shut off due to the inductive load of the coil of the electromagnetic clutch/brake. The protective element protects contact points from this reverse voltage.
Because powder clutches/brakes are rarely used in a manner in which they are turned on and off frequently, protective elements are not included.

Q2 What is the capacity of the clutch amplifier when clutches/brakes are connected in parallel and used simultaneously?

A Use in a manner in which the total rated current of the clutches/brakes is less than or equal to the output current of the clutch amplifier.
Example: What manual power supply is to be used when using two ZA-10Y1 powder brakes simultaneously?
Current of ZA-10Y1: 1.21 A
With two units: 1.21 A × 2 = 2.42 A
Therefore, a clutch amplifier with a current capacity of 2.42 A or more is required.

Q3 What is the orientation of the diode used for surge absorption?

A The cathode side is to be the positive (+) side.

11. Other

Q1 Can the shaft rotate to both the right and left?

A Because the shaft does not have a set rotation direction, it can be turned in either direction.

General information on electromagnetic clutches/brakes

General information on electromagnetic clutches/brakes

1. Calculating the load torque of machines

In many cases, it is difficult to calculate the net power required to operate a machine due to the setting of load conditions, transmission efficiency, etc. For this reason, it is often determined empirically. However, because it is necessary to understand the load torque in order to select an electromagnetic clutch, general formulas are listed below.
Note that there are many uncertainties as described above, so values should also be based on experience.

1.1 Torque from the motor

When the load torque is not clear and only the motor output is known, the following formula is used:

$$T_L = 9{,}550 \frac{P}{N} \eta \quad \text{......(1)}$$

where,

T_L: Load torque (N·m)
P: Motor rated output (kW)
N: Clutch shaft rotation speed (r/min)
η: Machine conduction efficiency from motor shaft to clutch shaft

1.2 Vertical motion work

Example: Hoisting

$$T_L = \frac{W \cdot V}{6.3N \cdot \eta} \quad \text{......(2)}$$

where,

T_L: Load torque (N·m)
W: Total weight (N) of vertically moving parts
V: Velocity of vertically moving parts (m/min)
N: Rotation speed of shaft for obtaining torque (r/min)
η: Efficiency
Example: Approx. 0.95 per pair of gears, chains, belts, etc.

Note: This formula can also be applied to lathe spindles that do similar work.
In this case, W should be cutting resistance (N)

1.3 Horizontal motion work with friction

Example: Table feeding, crane operation

$$T_L = \frac{\mu \cdot W \cdot V}{6.3N \cdot \eta} \quad \text{......(3)}$$

where,

μ: Running resistance (friction coefficient)
Ex:Approx. 0.005 for ball bearings
Approx. 0.15 on a bed surface*
W: Total weight (N) of horizontally moving parts
V: Velocity of horizontally moving parts (m/min)

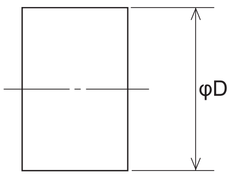
*: This may be even larger depending on the assembly/finishing condition of the machine.

2. Obtaining the load moment of inertia *J*

The moment of inertia J (kgm^2) of the rotating body can be obtained by the following equation, where the mass of the rotating body is M (kg) and the unit of length is (m).

2.1 Rotating body *J*

1. Solid cylindrical body



$$J = \frac{1}{8} \cdot M \cdot D^2 \text{ ....(1)}$$

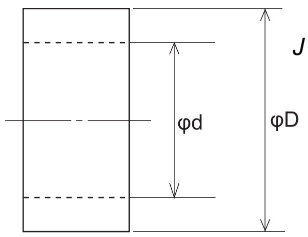
where,

J: Moment of inertia (kgm^2)

M: Mass (kg)

D: Outside diameter of rotating object (m)

2. Hollow cylindrical body



$$J = \frac{1}{8} M(D^2 + d^2) \text{ .....(2)}$$

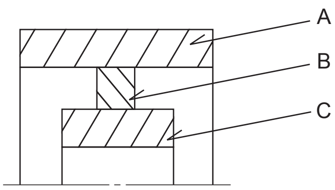
where,

d: Inside diameter of rotating object (m)

3. Complex shape

When the shape is as shown below, divide it into A, B, and C, find J of each part, and add them together. That is,

$J = J_A + J_B + J_C$ ....(3)



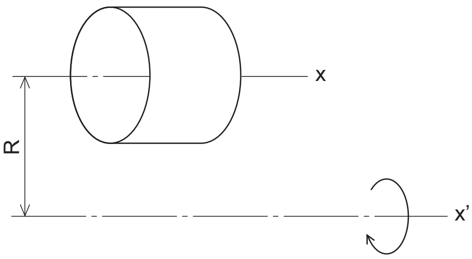
4. Any axis x' parallel to the center axis x passing through the center of gravity of an object

$J = J_X + M \cdot R^2$ .... (4)

where,

J_X: Moment of inertia of object with respect to axis x (kgm^2)

R: Distance between axes x and x' (m)



2.2 *J* for linear motion

(1) General formula

$$J = \frac{M \cdot V^2}{4\pi^2 \cdot N^2} \quad \text{.......................(5)}$$

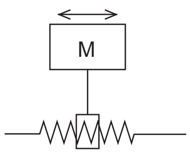
where, M: Mass of linearly moving object (kg)

V: Velocity of linearly moving object (m/min)

N: Rotation speed of the rotating shaft for obtaining *J* (r/min)

(2) *J* of various linear motion bodies

(1) When the object moves linearly with a screw [value on screw axis]



$$J = \frac{M}{4}\left(\frac{P}{\pi}\right)^2 \quad \text{..........(6)}$$

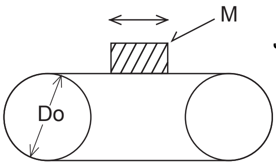
where,

P: Screw lead (m)

M: Mass of linearly moving object (kg)

(2) Conveyor [value on Do axis]

(However, *J* of the pulley/belt, etc., is not included.)

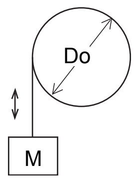


$$J = \frac{M}{4} Do^2 \quad \text{..........(7)}$$

where,

Do: Diameter of pulley, etc. (m)

(3) When the mass is moved by a rope, such as a crane/winch [value on drum axis]



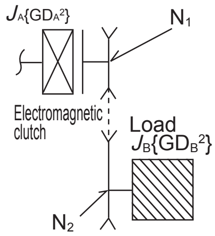
$$J = \frac{M}{4} Do^2 \quad \text{..........(8)}$$

where,

Do: Drum diameter (m)

2.3 Conversion of *J* to clutch shaft

To convert J_B on the N_2 shaft to the clutch shaft value as shown in the following figure, do as shown in the figure below.



$$J_A = \left(\frac{N_2}{N_1}\right)^2 \times J_B \quad \text{.........(9)}$$

where,

J_A: *J* at the clutch shaft (kgm²)

J_B: *J* on N_2 shaft (load shaft) (kgm²)

N_1: Rotation speed on the clutch shaft (r/min)

N_2: Rotation speed on the J_B shaft (r/min)

3. Quick reference table for load moment of inertia *J*

This table shows *J* (kgm^2) per 10 mm length at φ20 to φ1,000.

1. Steel with a specific gravity ρ = 7.85 is shown.
2. In case of a hollow cylindrical body, subtract *J* of the inside diameter from *J* of the outside diameter.
3. In the case of the following materials, apply the relevant coefficients to this table.
   Casting: × 0.92 Brass: × 1.14
   Aluminum: × 0.35
4. How to use the table
   The moment of inertia of a solid cylindrical body with a diameter of 352 mm and a thickness of 25 mm is determined from the table.
   Answer: From the intersection of row 350 on the left and column 2 at the top, 1.1832×10^{-1} kgm^2 is obtained, which is multiplied by the thickness 25 /10, hence: $J = 1.1832 \times 10^{-1} \times (25/10) = 0.2958$ kgm^2.

Diameter (mm)	*J* (kgm^2)									
	0	1	2	3	4	5	6	7	8	9
10	7.7×10^{-8}	1.13×10^{-7}	1.6×10^{-7}	2.2×10^{-7}	2.96×10^{-7}	3.9×10^{-7}	5.05×10^{-7}	6.44×10^{-7}	8.09×10^{-7}	1×10^{-6}
20	1.23×10^{-6}	1.5×10^{-6}	1.81×10^{-6}	2.16×10^{-6}	2.56×10^{-6}	3.01×10^{-6}	3.52×10^{-6}	4.1×10^{-6}	4.74×10^{-6}	5.45×10^{-6}
30	6.24×10^{-6}	7.12×10^{-6}	8.08×10^{-6}	9.14×10^{-6}	1.03×10^{-5}	1.157×10^{-5}	1.294×10^{-5}	1.444×10^{-5}	1.607×10^{-5}	1.783×10^{-5}
40	1.973×10^{-5}	2.178×10^{-5}	2.398×10^{-5}	2.635×10^{-5}	2.889×10^{-5}	3.16×10^{-5}	3.451×10^{-5}	3.761×10^{-5}	4.091×10^{-5}	4.443×10^{-5}
50	4.817×10^{-5}	5.214×10^{-5}	5.635×10^{-5}	6.081×10^{-5}	6.553×10^{-5}	7.052×10^{-5}	7.579×10^{-5}	8.135×10^{-5}	8.721×10^{-5}	9.339×10^{-5}
60	9.988×10^{-5}	1.067×10^{-4}	1.139×10^{-4}	1.214×10^{-4}	1.293×10^{-4}	1.376×10^{-4}	1.462×10^{-4}	1.553×10^{-4}	1.648×10^{-4}	1.747×10^{-4}
70	1.85×10^{-4}	1.958×10^{-4}	2.071×10^{-4}	2.189×10^{-4}	2.311×10^{-4}	2.438×10^{-4}	2.571×10^{-4}	2.709×10^{-4}	2.853×10^{-4}	3.002×10^{-4}
80	3.157×10^{-4}	3.317×10^{-4}	3.484×10^{-4}	3.657×10^{-4}	3.837×10^{-4}	4.023×10^{-4}	4.216×10^{-4}	4.415×10^{-4}	4.622×10^{-4}	4.835×10^{-4}
90	5.056×10^{-4}	5.285×10^{-4}	5.521×10^{-4}	5.765×10^{-4}	6.017×10^{-4}	6.277×10^{-4}	6.546×10^{-4}	6.823×10^{-4}	7.18×10^{-4}	7.403×10^{-4}
100	7.707×10^{-4}	8.02×10^{-4}	8.342×10^{-4}	8.674×10^{-4}	9.016×10^{-4}	9.368×10^{-4}	9.73×10^{-4}	1.01×10^{-3}	1.048×10^{-3}	1.088×10^{-3}
110	1.128×10^{-3}	1.17×10^{-3}	1.213×10^{-3}	1.257×10^{-3}	1.302×10^{-3}	1.348×10^{-3}	1.395×10^{-3}	1.444×10^{-3}	1.494×10^{-3}	1.545×10^{-3}
120	1.598×10^{-3}	1.652×10^{-3}	1.707×10^{-3}	1.764×10^{-3}	1.822×10^{-3}	1.882×10^{-3}	1.942×10^{-3}	2.005×10^{-3}	2.069×10^{-3}	2.134×10^{-3}
130	2.201×10^{-3}	2.27×10^{-3}	2.34×10^{-3}	2.411×10^{-3}	2.485×10^{-3}	2.56×10^{-3}	2.636×10^{-3}	2.715×10^{-3}	2.795×10^{-3}	2.877×10^{-3}
140	2.961×10^{-3}	3.046×10^{-3}	3.133×10^{-3}	3.223×10^{-3}	3.314×10^{-3}	3.407×10^{-3}	3.502×10^{-3}	3.599×10^{-3}	3.698×10^{-3}	3.799×10^{-3}
150	3.902×10^{-3}	4.007×10^{-3}	4.114×10^{-3}	4.223×10^{-3}	4.335×10^{-3}	4.448×10^{-3}	4.564×10^{-3}	4.682×10^{-3}	4.803×10^{-3}	4.926×10^{-3}
160	5.051×10^{-3}	5.178×10^{-3}	5.308×10^{-3}	5.44×10^{-3}	5.575×10^{-3}	5.712×10^{-3}	5.852×10^{-3}	5.994×10^{-3}	6.139×10^{-3}	6.287×10^{-3}
170	6.437×10^{-3}	6.59×10^{-3}	6.745×10^{-3}	6.903×10^{-3}	7.064×10^{-3}	7.228×10^{-3}	7.395×10^{-3}	7.564×10^{-3}	7.737×10^{-3}	7.912×10^{-3}
180	8.09×10^{-3}	8.272×10^{-3}	8.456×10^{-3}	8.643×10^{-3}	8.834×10^{-3}	9.027×10^{-3}	9.224×10^{-3}	9.424×10^{-3}	9.627×10^{-3}	9.834×10^{-3}
190	1.004×10^{-2}	1.026×10^{-2}	1.047×10^{-2}	1.069×10^{-2}	1.092×10^{-2}	1.114×10^{-2}	1.137×10^{-2}	1.161×10^{-2}	1.184×10^{-2}	1.209×10^{-2}
200	1.233×10^{-2}	1.258×10^{-2}	1.283×10^{-2}	1.309×10^{-2}	1.335×10^{-2}	1.361×10^{-2}	1.388×10^{-2}	1.415×10^{-2}	1.443×10^{-2}	1.47×10^{-2}
210	1.499×10^{-2}	1.528×10^{-2}	1.557×10^{-2}	1.586×10^{-2}	1.616×10^{-2}	1.647×10^{-2}	1.678×10^{-2}	1.709×10^{-2}	1.741×10^{-2}	1.773×10^{-2}
220	1.805×10^{-2}	1.838×10^{-2}	1.872×10^{-2}	1.906×10^{-2}	1.94×10^{-2}	1.975×10^{-2}	2.011×10^{-2}	2.046×10^{-2}	2.083×10^{-2}	2.119×10^{-2}
230	2.157×10^{-2}	2.194×10^{-2}	2.233×10^{-2}	2.271×10^{-2}	2.311×10^{-2}	2.35×10^{-2}	2.391×10^{-2}	2.431×10^{-2}	2.473×10^{-2}	2.515×10^{-2}
240	2.557×10^{-2}	2.6×10^{-2}	2.643×10^{-2}	2.687×10^{-2}	2.732×10^{-2}	2.777×10^{-2}	2.822×10^{-2}	2.869×10^{-2}	2.915×10^{-2}	2.963×10^{-2}
250	3.01×10^{-2}	3.059×10^{-2}	3.108×10^{-2}	3.158×10^{-2}	3.208×10^{-2}	3.259×10^{-2}	3.31×10^{-2}	3.362×10^{-2}	3.415×10^{-2}	3.468×10^{-2}
260	3.522×10^{-2}	3.576×10^{-2}	3.631×10^{-2}	3.687×10^{-2}	3.744×10^{-2}	3.801×10^{-2}	3.858×10^{-2}	3.917×10^{-2}	3.976×10^{-2}	4.035×10^{-2}
270	4.096×10^{-2}	4.157×10^{-2}	4.218×10^{-2}	4.281×10^{-2}	4.344×10^{-2}	4.408×10^{-2}	4.472×10^{-2}	4.537×10^{-2}	4.603×10^{-2}	4.67×10^{-2}
280	4.737×10^{-2}	4.805×10^{-2}	4.874×10^{-2}	4.943×10^{-2}	5.014×10^{-2}	5.084×10^{-2}	5.156×10^{-2}	5.299×10^{-2}	5.302×10^{-2}	5.376×10^{-2}
290	5.451×10^{-2}	5.526×10^{-2}	5.603×10^{-2}	5.68×10^{-2}	5.758×10^{-2}	5.837×10^{-2}	5.916×10^{-2}	5.996×10^{-2}	6.078×10^{-2}	6.16×10^{-2}
300	6.242×10^{-2}	6.326×10^{-2}	6.411×10^{-2}	6.496×10^{-2}	6.582×10^{-2}	6.669×10^{-2}	6.757×10^{-2}	6.846×10^{-2}	6.935×10^{-2}	7.026×10^{-2}
310	7.117×10^{-2}	7.21×10^{-2}	7.303×10^{-2}	7.397×10^{-2}	7.492×10^{-2}	7.588×10^{-2}	7.685×10^{-2}	7.782×10^{-2}	7.881×10^{-2}	7.981×10^{-2}
320	8.081×10^{-2}	8.183×10^{-2}	8.285×10^{-2}	8.388×10^{-2}	8.493×10^{-2}	8.598×10^{-2}	8.704×10^{-2}	8.812×10^{-2}	8.92×10^{-2}	9.029×10^{-2}
330	9.14×10^{-2}	9.251×10^{-2}	9.363×10^{-2}	9.476×10^{-2}	9.591×10^{-2}	9.706×10^{-2}	9.823×10^{-2}	9.94×10^{-2}	1.0059×10^{-1}	1.0178×10^{-1}
340	1.0299×10^{-1}	1.0421×10^{-1}	1.0543×10^{-1}	1.0667×10^{-1}	1.0792×10^{-1}	1.0918×10^{-1}	1.1045×10^{-1}	1.1174×10^{-1}	1.1303×10^{-1}	1.1433×10^{-1}
350	1.1565×10^{-1}	1.1698×10^{-1}	1.1832×10^{-1}	1.1967×10^{-1}	1.2103×10^{-1}	1.224×10^{-1}	1.2379×10^{-1}	1.2581×10^{-1}	1.2659×10^{-1}	1.2801×10^{-1}
360	1.2944×10^{-1}	1.3089×10^{-1}	1.3234×10^{-1}	1.3381×10^{-1}	1.3529×10^{-1}	1.3679×10^{-1}	1.3829×10^{-1}	1.3981×10^{-1}	1.4134×10^{-1}	1.4288×10^{-1}
370	1.4444×10^{-1}	1.4601×10^{-1}	1.4759×10^{-1}	1.4918×10^{-1}	1.5079×10^{-1}	1.524×10^{-1}	1.5404×10^{-1}	1.5568×10^{-1}	1.5734×10^{-1}	1.5901×10^{-1}
380	1.607×10^{-1}	1.6239×10^{-1}	1.6411×10^{-1}	1.6583×10^{-1}	1.6757×10^{-1}	1.6933×10^{-1}	1.7109×10^{-1}	1.7287×10^{-1}	1.7466×10^{-1}	1.7647×10^{-1}
390	1.7829×10^{-1}	1.8013×10^{-1}	1.8198×10^{-1}	1.8384×10^{-1}	1.8572×10^{-1}	1.8761×10^{-1}	1.8952×10^{-1}	1.9144×10^{-1}	1.9338×10^{-1}	1.9533×10^{-1}
400	1.9729×10^{-1}	1.9927×10^{-1}	2.0127×10^{-1}	2.0328×10^{-1}	2.053×10^{-1}	2.0734×10^{-1}	2.094×10^{-1}	2.1147×10^{-1}	2.1356×10^{-1}	2.1566×10^{-1}
410	2.1777×10^{-1}	2.1991×10^{-1}	2.2205×10^{-1}	2.2422×10^{-1}	2.264×10^{-1}	2.2859×10^{-1}	2.308×10^{-1}	2.3303×10^{-1}	2.3528×10^{-1}	2.3753×10^{-1}
420	2.3981×10^{-1}	2.421×10^{-1}	2.4441×10^{-1}	2.4674×10^{-1}	2.4908×10^{-1}	2.5144×10^{-1}	2.5381×10^{-1}	2.562×10^{-1}	2.5861×10^{-1}	2.6104×10^{-1}
430	2.6348×10^{-1}	2.6594×10^{-1}	2.6841×10^{-1}	2.7091×10^{-1}	2.7342×10^{-1}	2.7595×10^{-1}	2.7849×10^{-1}	2.8106×10^{-1}	2.8364×10^{-1}	2.8624×10^{-1}
440	2.8886×10^{-1}	2.9149×10^{-1}	2.9414×10^{-1}	2.9681×10^{-1}	2.995×10^{-1}	3.0221×10^{-1}	3.0494×10^{-1}	3.0768×10^{-1}	3.1044×10^{-1}	3.1322×10^{-1}
450	3.1602×10^{-1}	3.1884×10^{-1}	3.2168×10^{-1}	3.2454×10^{-1}	3.2741×10^{-1}	3.3031×10^{-1}	3.3322×10^{-1}	3.3615×10^{-1}	3.391×10^{-1}	3.4208×10^{-1}
460	3.4507×10^{-1}	3.4808×10^{-1}	3.5111×10^{-1}	3.5416×10^{-1}	3.5723×10^{-1}	3.6032×10^{-1}	3.6342×10^{-1}	3.6655×10^{-1}	3.697×10^{-1}	3.7287×10^{-1}
470	3.7606×10^{-1}	3.7927×10^{-1}	3.8251×10^{-1}	3.8576×10^{-1}	3.8903×10^{-1}	3.9232×10^{-1}	3.9564×10^{-1}	3.9897×10^{-1}	4.0233×10^{-1}	4.0571×10^{-1}
480	4.0911×10^{-1}	4.1253×10^{-1}	4.1597×10^{-1}	4.1943×10^{-1}	4.2291×10^{-1}	4.2642×10^{-1}	4.2995×10^{-1}	4.335×10^{-1}	4.3707×10^{-1}	4.4066×10^{-1}
490	4.4428×10^{-1}	4.4792×10^{-1}	4.5158×10^{-1}	4.5526×10^{-1}	4.5886×10^{-1}	4.6269×10^{-1}	4.6644×10^{-1}	4.7021×10^{-1}	4.7401×10^{-1}	4.7783×10^{-1}
500	4.8167×10^{-1}	4.8554×10^{-1}	4.8942×10^{-1}	4.9334×10^{-1}	4.9727×10^{-1}	5.0123×10^{-1}	5.0521×10^{-1}	5.0922×10^{-1}	5.1325×10^{-1}	5.173×10^{-1}

● How to calculate *J*

Steel: $J = D^4 \times L \times 775$ [kgm^2]

Brass: $J = D^4 \times L \times 880$ [kgm^2]

Aluminum: $J = D^4 \times L \times 270$ [kgm^2]

where, D: diameter (m), L: length (m)

Diameter (mm)	*J* (kgm^2)									
	0	1	2	3	4	5	6	7	8	9
510	5.2138 ×10^{-1}	5.2548 ×10^{-1}	5.296 ×10^{-1}	5.3375 ×10^{-1}	5.3793 ×10^{-1}	5.4212 ×10^{-1}	5.4635 ×10^{-1}	5.506 ×10^{-1}	5.5487 ×10^{-1}	5.5916 ×10^{-1}
520	5.6349 ×10^{-1}	5.6783 ×10^{-1}	5.7221 ×10^{-1}	5.766 ×10^{-1}	5.8103 ×10^{-1}	5.8547 ×10^{-1}	5.8995 ×10^{-1}	5.9445 ×10^{-1}	5.9897 ×10^{-1}	6.0352 ×10^{-1}
530	6.081 ×10^{-1}	6.127 ×10^{-1}	6.1733 ×10^{-1}	6.2198 ×10^{-1}	6.2666 ×10^{-1}	6.3137 ×10^{-1}	6.3611 ×10^{-1}	6.4087 ×10^{-1}	6.4565 ×10^{-1}	6.5047 ×10^{-1}
540	6.5531 ×10^{-1}	6.6018 ×10^{-1}	6.6507 ×10^{-1}	6.6999 ×10^{-1}	6.7494 ×10^{-1}	6.7992 ×10^{-1}	6.8492 ×10^{-1}	6.8995 ×10^{-1}	6.9501 ×10^{-1}	7.001 ×10^{-1}
550	7.0521 ×10^{-1}	7.1036 ×10^{-1}	7.1553 ×10^{-1}	7.2073 ×10^{-1}	7.2595 ×10^{-1}	7.3121 ×10^{-1}	7.3649 ×10^{-1}	7.4181 ×10^{-1}	7.4715 ×10^{-1}	7.5252 ×10^{-1}
560	7.5792 ×10^{-1}	7.6335 ×10^{-1}	7.688 ×10^{-1}	7.7429 ×10^{-1}	7.7981 ×10^{-1}	7.8535 ×10^{-1}	7.9093 ×10^{-1}	7.9653 ×10^{-1}	8.0216 ×10^{-1}	8.0783 ×10^{-1}
570	8.1352 ×10^{-1}	8.1925 ×10^{-1}	8.25 ×10^{-1}	8.3078 ×10^{-1}	8.366 ×10^{-1}	8.4244 ×10^{-1}	8.4832 ×10^{-1}	8.5423 ×10^{-1}	8.6016 ×10^{-1}	8.6613 ×10^{-1}
580	8.7213 ×10^{-1}	8.7816 ×10^{-1}	8.8422 ×10^{-1}	8.9032 ×10^{-1}	8.9644 ×10^{-1}	9.026 ×10^{-1}	9.0878 ×10^{-1}	9.15 ×10^{-1}	9.2125 ×10^{-1}	9.2754 ×10^{-1}
590	9.3385 ×10^{-1}	9.402 ×10^{-1}	9.4658 ×10^{-1}	9.5299 ×10^{-1}	9.5944 ×10^{-1}	9.6591 ×10^{-1}	9.7242 ×10^{-1}	9.7897 ×10^{-1}	9.8554 ×10^{-1}	9.9215 ×10^{-1}
600	9.9879 ×10^{-1}	1.0055	1.0122	1.0189	1.0257	1.0325	1.0394	1.0462	1.0531	1.0601
610	1.0671	1.0741	1.0811	1.0882	1.0953	1.1025	1.1097	1.1169	1.1242	1.1315
620	1.1388	1.1461	1.1535	1.1610	1.1685	1.1760	1.1835	1.1911	1.1987	1.2064
630	1.2140	1.2218	1.2295	1.2373	1.2452	1.2530	1.2610	1.2689	1.2769	1.2849
640	1.2930	1.3011	1.3092	1.3174	1.3256	1.3339	1.3422	1.3505	1.3589	1.3673
650	1.3757	1.3842	1.3927	1.4013	1.4099	1.4185	1.4272	1.4359	1.4447	1.4535
660	1.4623	1.4712	1.4801	1.4891	1.4981	1.5072	1.5162	1.5254	1.5345	1.5437
670	1.5530	1.5623	1.5716	1.5810	1.5904	1.5999	1.6094	1.6189	1.6285	1.6381
680	1.6478	1.6575	1.6673	1.6771	1.6859	1.6968	1.7067	1.7167	1.7267	1.7368
690	1.7469	1.7570	1.7672	1.7775	1.7878	1.7981	1.8085	1.8189	1.8293	1.8398
700	1.8504	1.8610	1.8716	1.8823	1.8931	1.9038	1.9147	1.9255	1.9364	1.9474
710	1.9584	1.9695	1.9806	1.9917	2.0029	2.0142	2.0255	2.0368	2.0482	2.0592
720	2.0711	2.0826	2.0942	2.1058	2.1175	2.2192	2.1410	2.1528	2.1647	2.1766
730	2.1886	2.2006	2.2127	2.2248	2.2369	2.2492	2.2614	2.2737	2.2861	2.2985
740	2.3110	2.3235	2.3361	2.3487	2.3614	2.3741	2.3869	2.3997	2.4126	2.4255
750	2.4385	2.4515	2.4646	2.4777	2.4909	2.5041	2.5174	2.5308	2.5442	2.5576
760	2.5711	2.5847	2.5983	2.6120	2.6257	2.6395	2.6533	2.6672	2.6811	2.6951
770	2.7092	2.7233	2.7374	2.7516	2.7659	2.7802	2.7946	2.8090	2.8235	2.8381
780	2.8527	2.8673	2.8820	2.8968	2.9116	2.9265	2.9414	2.9564	2.9715	2.9866
790	3.0018	3.0170	3.0323	3.0476	3.0630	3.0785	3.0940	3.1096	3.1252	3.1409
800	3.1567	3.1725	3.1884	3.2043	3.2203	3.2363	3.2525	3.2686	3.2849	3.3011
810	3.3175	3.3339	3.3504	3.3669	3.3835	3.4002	3.4169	3.4337	3.4505	3.4674
820	3.4844	3.5014	3.5185	3.5357	3.5529	3.5701	3.5875	3.6049	3.6224	3.6399
830	3.6575	3.6751	3.6929	3.7107	3.7285	3.7464	3.7644	3.7824	3.8006	3.8187
840	3.8370	3.8553	3.8736	3.8921	3.9106	3.9291	3.9478	3.9665	3.9852	4.0041
850	4.0230	4.0419	4.0610	4.0801	4.0992	4.1185	4.1378	4.1571	4.1766	4.1961
860	4.2156	4.2353	4.2550	4.2748	4.2946	4.3145	4.3345	4.3546	4.3747	4.3949
870	4.4152	4.4355	4.4559	4.4764	4.4969	4.5175	4.5382	4.5590	4.5798	4.6007
880	4.6217	4.6427	4.6639	4.6850	4.7063	4.7276	4.7490	4.7705	4.7921	4.8137
890	4.8354	4.8571	4.8790	4.9009	4.9229	4.9450	4.9671	4.9893	5.0116	5.0340
900	5.0564	5.0789	5.1015	5.1241	5.1469	5.1697	5.1926	5.2155	5.2386	5.2617
910	5.2849	5.3082	5.3315	5.3549	5.3784	5.4020	5.4257	5.4494	5.4732	5.4971
920	5.5210	5.5451	5.5692	5.5934	5.6177	5.6421	5.6665	5.6910	5.7156	5.7403
930	5.7650	5.7899	5.8148	5.8398	5.8649	5.8900	5.9153	5.9406	5.9660	5.9915
940	6.0170	6.0427	6.0684	6.0942	6.1201	6.1461	6.1721	6.1983	6.2245	6.2508
950	6.2772	6.3037	6.3302	6.3568	6.3836	6.4104	6.4373	6.4642	6.4913	6.5185
960	6.5457	6.5730	6.6004	6.6279	6.6555	6.6831	6.7109	6.7387	6.7666	6.7946
970	6.8227	6.8509	6.8792	6.9075	6.9359	6.9645	6.9931	7.0218	7.0506	7.0795
980	7.1084	7.1375	7.1666	7.1959	7.2252	7.2546	7.2841	7.3137	7.3434	7.3732
990	7.4031	7.4330	7.4631	7.4932	7.5234	7.5537	7.5842	7.6147	7.6453	7.6759
1000	7.7067	7.7376	7.7686	7.7996	7.8308	7.8620	7.8934	7.9248	7.9563	7.9879

4. Electromagnetic clutch/brake terminology (excerpt)

(Japan Machine Tool Builders' Association Standard TES 1105)

4.1 Application scope

This standard defines terms and meanings for friction type, interlocking type, air gap type, and lap spring type electromagnetic clutches and brakes (hereinafter, referred to as clutches and brakes).

4.2 Terminology classifications

Clutch and brake terms are classified as follows.
(1) Names (2) Operation Terms (3) Performance Terms

4.3 No./Term/Meaning

Numbers, terms, and their meanings are as follows. Quantity symbols, units, applicable models, and corresponding English are shown for reference.

(1) Names

No.	Term	Meaning
101	Electromagnetic clutch	An element that operates electromagnetically to transmit/ interrupt torque from the drive side on a concentric axis to the driven side.
106	Electromagnetic gap type clutch	An electromagnetic clutch with an air gap between the drive side and the driven side.
107	Electromagnetic particle clutch, electromagnetic powder clutch	An electromagnetic clutch that uses powder enclosed in an air gap as a medium for transmitting torque.
108	Hysteresis clutch	An electromagnetic clutch that utilizes the hysteresis characteristics of magnetic materials.
121	Electromagnetic brake	An element that operates electromagnetically to decelerate, stop, or hold a rotating body in a stopped state or a certain state.
126	Electromagnetic gap type brake	An electromagnetic brake with an air gap between stationary and rotating parts.
127	Electromagnetic particle brake, electromagnetic powder brake	An electromagnetic brake that uses powder enclosed in an air gap as a medium for transmitting torque.
128	Hysteresis brake	An electromagnetic brake that utilizes the hysteresis characteristics of magnetic materials.
145	Stationary coil type	A type with a stationary coil.
146	Rotating coil type	A type with a rotating coil.
162	Water cooling type	A type that cools generated heat using water.
163	Air cooling type	A type that cools generated heat using air.

(2) Operation Terms

No.	Term	Meaning	Quantity symbol	Unit	Applicable model
301	Engaging of clutch	The clutch operates to synchronize the driven side with the drive side.			Same for all models
302	Braking	Activation of the brake.			Same for all models
303	Electromagnetic operation, electromagnetic actuation	Activation or releasing of the clutch and brake via electromagnetic force.			Same for all models
304	Shockless engaging of clutch (cushioned start)	Gradual transmission of torque from the drive side to the driven side via the clutch in order to synchronize the driven side without shock.			Friction types, air gap types
305	Shockless braking	Deceleration or stopping of the object to be braked via brake without shock.			Friction types, air gap types
306	Slip service	Operation of the clutch and brake while sliding them continuously.			Friction types, air gap types
309	Stationary engagement of clutch	Engagement of the clutch in a stationary state.			Same for all models
310	Rotating engagement of clutch	Engagement of the clutch in a rotating state.			Same for all models
311	Engaging frequency	The number of times a clutch operates within a unit time.	Ne	times/s times/min	Same for all models
312	Braking frequency	The number of times a brake operates within a unit time.	Nb	times/s times/min	Same for all models
313	Exciting time ratio	The ratio (expressed as a percentage) between the time during which a coil is excited by the clutch/brake and the time of one cycle.	%ED	%	Same for all models
314	Rotating time ratio	The ratio (expressed as a percentage) between the time during which a rotating body is rotated and the time of one cycle.	%RT	%	Same for all models
315	Over excitation	When a voltage higher than the rated voltage is instantly applied to accelerate clutch/brake responsiveness and increase generated torque.			Same for all models
316	Weak excitation	When a voltage lower than the rated voltage is applied to cushion the clutch/brake and decrease the generated torque.			Same for all models
317	Quick response excitation	When responsiveness is accelerated with the clutch/brake to excite with a circuit with a small time constant.			Same for all models
318	Quick response over excitation	When both overexcitation and rapid excitation are used to further accelerate response and increase generated torque with the clutch/brake.			Same for all models
319	Drag	When drag torque (idling torque) causes the driven side to be rotated via the clutch and braking applied via the brake.			Same for all models
320	Torque wrap	Interference between the damping torque and generated torque when two clutches or brakes are operated together, in turn affecting the engaging time, braking time, or wear.			Same for all models
321	To engage	Engagement of the clutch.			Same for all models
322	To disengage	Releasing of the clutch from an engaged state.			Same for all models
323	To apply the brake	Activation of the brake.			Same for all models
324	To take off the brake, to release the brake	Releasing of the brake from an operating state.			Same for all models

(3) Performance Terms

No.	Term	Meaning	Quantity symbol	Unit	Applicable model
401	Rated torque	The guaranteed torque usage limit for clutches and brakes.	Tr	N·m	Same for all models
406	Load torque	A general term referring to load-side torque that appears as resistance torque or braking torque when the clutch or brake operates.	Tl	N·m	Same for all models
407	Decreasing torque	Transient torque that occurs during the transition from the shutting off of current via the clutch/brake to the generation of drag torque (idling torque).			Same for all models
408	Drag torque residual torque	Torque generated when the clutch/brake are not operating.	Tdg	N·m	Same for all models
414	Braking force	Force that decelerates, stops, or holds the braking object in position.	Fn	N	Same for all models
421	Total engaging time (total engagement time)	The time from when operation input is input via the clutch until clutch engagement is completed.	tte	s	Same for all models
422	Engaging time	The time from when operation input is input to the clutch unit until engagement is completed.	te	s	Same for all models
423	Actual engaging time (actual engagement time)	The time from when torque begins to be generated via the clutch until engagement is completed.	tae	s	Same for all models
424	Total braking time	The time from when operation input is input via the brake until braking by the brake is completed.	ttb	s	Same for all models
425	Braking time	The time from when operation input is input to the brake unit until movement is stopped, or the time until deceleration is completed.	tb	s	Same for all models
426	Actual braking time	The time from when torque is generated via the brake until braking is completed.	tab	s	Same for all models
427	Response time	A general term referring to engaging time and braking time.	tr	s	Same for all models
428	Initial delay time	The time from when operation input is input via the clutch/brake until the operation input or release input is input to the clutch/brake unit.	tid	s	Same for all models
431	Torque build-up time	The time from when operation input is input to the clutch/brake until it reaches 80% of the rated dynamic friction torque. For air gap type clutches/brakes, the rated dynamic friction torque is the rated torque.	tp	s	Friction types, air gap types
432	Actual torque build-up time	The time from when torque is generated via the clutch/brake until it reaches 80% of the rated dynamic friction torque. For air gap type clutches/brakes, the rated dynamic friction torque is the rated torque.	tap	s	Friction types, air gap types
433	Torque decaying time	The time from when release input is issued to the clutch/brake unit until it reaches 10% of the rated torque. The rated torque is the static friction torque in the case of the dry type and the dynamic friction torque in the case of the wet type.	td	s	Friction types, air gap types
434	Release time (disengagement time)	The time from when operation input for stopping the operation is input to the clutch/ brake until disengagement or until braking is released.	tre	s	Same for all models

No.	Term	Meaning	Quantity symbol	Unit	Applicable model
435	Time to zero speed	The time until output rotation becomes zero after the release input operation of the excitation-operated clutch or the operation input operation of the non-excitation-operated clutch.		s	Same for all models
441	Engaging energy	The energy when engaging the drive side and the driven side via a clutch.	Ee	J	Friction types, air gap types
442	Engaging energy rate	The engaging energy per unit time.	Pe	W	Friction types, air gap types
443	Allowable engaging energy	The allowable energy when engaging the clutch drive side and driven side.	Eeal	J	Friction types, air gap types
444	Allowable engaging energy rate	The allowed energy rate when engaging the drive side and driven side via the clutch.	Peal	W	Friction types, air gap types
445	Braking energy	The energy when braking via the brake.	Eb	J	Friction types, air gap types
446	Braking energy rate	The braking energy per unit time.	Pb	W	Friction types, air gap types
447	Allowable braking energy	The allowable energy when braking via the brake.	Ebal	J	Friction types, air gap types
448	Allowable braking energy rate	The allowable energy rate when braking via the brake.	Pbal	W	Friction types, air gap types
449	Heat dissipation capacity	The ability to dissipate the heat generated by friction energy by clutches/brakes.	Cd	W	Friction types, air gap types
450	Continuous heat dissipation	The energy rate when continuous sliding operation is performed.	Ps	W	Friction types, air gap types
451	Allowable continuous heat dissipation	The allowable energy rate when continuous sliding operation is performed.	Psal	W	Friction types, air gap types
461	Rated voltage	A reference value for when voltage is applied to the clutch/brake.		V	Same for all models
465	Rated current	The current that flows through the coil when the rated voltage is applied at a coil temperature of 75°C via the clutch/brake.		A	Same for all models
474	Slipping velocity	The speed at which the clutch/brake slips on the working surface.	V	m/s	Friction types, air gap types
475	Moment of inertia	The value indicated by the product of the square of mass m (kg) of the rotating body and radius R (m) of the rotating body.	*J*	kgm^2	Same for all models
476	Fly-wheel effect	The value indicated by the product of the square of weight G (kgf) of the rotating body and diameter D (m) of the rotating body.	GD^2		Same for all models
481	Torque-to-size ratio	The ratio between the outer diameter or length of the clutch/brake and the rated torque. Note: If rated torque is Tr, outer diameter is D, and length is L, it is expressed as D/Tr or L/Tr.	bal		Same for all models
482	Torque-to-time characteristic	The transient characteristic of torque when the clutch/brake operate.			Same for all models
483	Torque-to-slip characteristic	The torque characteristic for changes in clutch/brake slip speed.			Friction types, air gap types
484	Torque-to-current characteristic	A characteristic that expresses the relationship between the excitation current and torque of the clutches/brakes.			Friction types, air gap types, interlocking types

5. List of formulas used for selection of electromagnetic clutch/brake models

Calculation of torque	$T = \frac{9{,}550P}{N} = \frac{7{,}017P'}{N} = \frac{7{,}154P''}{N}$
Calculation of average dynamic friction torque	1. When there is no load torque $T_{ae}\ (\text{or } T_{ab}) = \frac{J \cdot Nr}{9.55\, t_{ae}\ (\text{or } t_{ab})}$ 2. When there is load torque Startup acceleration $T_{ae} = \frac{J \cdot Nr}{9.55 t_{ae}} + T_L$ Deceleration stop $T_{ab} = \frac{J \cdot Nr}{9.55 t_{ab}} - T_L$
Calculation of operation time	1. When there is no load torque $t_{ae} = t_{ab} = \frac{2\pi \cdot J \cdot Nr}{60 T_d} = \frac{J \cdot Nr}{9.55 T_d}$ 2. When there is load torque Startup acceleration $t_{ae} = \frac{2\pi \cdot J \cdot Nr}{60\ (T_d - T_L)} = \frac{J \cdot Nr}{9.55\ (T_d - T_L)}$ Deceleration stop $t_{ab} = \frac{2\pi \cdot J \cdot Nr}{60\ (T_d + T_L)} = \frac{J \cdot Nr}{9.55\ (T_d + T_L)}$
Explanation of symbols	T: Torque (N·m) P: Motor output (kw) P': Motor output (HP or hp) P": Motor output (PS) N: Clutch/brake shaft rotation speed (r/min) T_{ae}: Average dynamic friction torque of the clutch (N·m) T_{ab}: Average dynamic friction torque of the brake (N·m) J: Total moment of inertia for clutch/brake shaft conversion (kgm^2) Nr: Clutch/brake shaft relative rotation speed (r/min) t_{ae}: Actual clutch engaging time (s) t_{ab}: Actual brake braking time (s) T_L: Load torque (N·m) T_d: Clutch/brake dynamic friction torque (N·m)

Calculation of energy	1. When there is no load torque $E_e = E_b = \frac{J \cdot Nr^2}{182}$ 2. When there is load torque Startup acceleration $E_e = \frac{J \cdot Nr^2}{182} \cdot \frac{T_d}{T_d - T_L}$ Deceleration stop $E_b = \frac{J \cdot Nr^2}{182} \cdot \frac{T_d}{T_d + T_L}$
Calculation of energy rate	1. When there is no load torque $P_e = P_b = \frac{J \cdot Nr^2}{182} \cdot \frac{f}{60}$ 2. When there is load torque Startup acceleration $P_e = \frac{J \cdot Nr^2}{182} \cdot \frac{T_d}{T_d - T_L} \cdot \frac{f}{60}$ Deceleration stop $P_b = \frac{J \cdot Nr^2}{182} \cdot \frac{T_d}{T_d + T_L} \cdot \frac{f}{60}$
Calculation of lifespan	$L_e\ (\text{or } L_b) = \frac{V}{e \cdot E_e\ (\text{or } E_b)} = \frac{E_t}{E_e\ (\text{or } E_b)}$
Explanation of symbols	E_e: Clutch engaging energy (J) E_b: Brake braking energy (J) J: Total moment of inertia for clutch/brake shaft conversion (kgm^2) Nr: Clutch/brake shaft relative rotation speed (r/min) T_d: Clutch/brake dynamic friction torque (N·m) T_L: Load torque (N·m) P_e: Clutch engaging energy rate (W) P_b: Brake braking energy rate (W) f: Clutch/brake operation frequency (times/min) L_e: Number of engagements until end of clutch lifespan (times) L_b: Number of braking operations until end of brake lifespan (times) V: Total volume of friction parts until wear limit (cm^3) e: Wear ratio (cm^3/J) E_t: Total energy until wear limit (J)

SI Unit and Non-SI Unit Conversion Table

The transition to SI units has been carried out since October 1, 1999, but some terms still require conversion. The following reference table shows conversion factors related to clutches and brakes.

Physical quantity	Non-SI unit (symbol)	SI unit (symbol)	Conversion relation
Length	Micron (μ)	Meter (m)	1 μ = 1 μm
Frequency	Cycle (c) Cycle per second (c/s)	Hertz (Hz)	1 c = 1 c/s = 1 Hz
Magnetic field strength	Amperage per meter (AT/m) Oersted (Oe)	Ampere meter (A/m)	1 AT/m = 1 A/m 1 Oe ≈ 79 A/m
Magnetomotive force	Ampere-turn (AT)	Ampere (A)	1 AT = 1 A
Magnetic flux density	Gamma (γ) Gauss (G)	Tesla (T)	1 γ = 1 nT 1 G = 100 μT
Magnetic flux density	Maxwell (Mx)	Weber (Wb)	1 Mx = 10 nWb
Sound pressure level	Phon	Decibel (dB)	1 phon = 1 dB
Force (load and tension)	Weight kg (kgf) Weight gram (gf) Weight ton (tf)	Newton (N)	1 kgf ≈ 9.8 N 1 gf ≈ 9.8 mN 1 tf ≈ 9.8 kN
Moment of force (torque)	Weight kilogram meter (kgf·m)	Newton meter (N·m)	1 kgf·m ≈ 9.8 N·m
Pressure	Weight kilogram per square meter (kgf/m^2)	Pascal (Pa)	1 kgf/m^2 ≈ 9.8 Pa
Stress	Weight kilogram per square meter (kgf/m^2)	Pascal (Pa)	1 kgf/m^2 ≈ 9.8 Pa
Work (energy)	Weight kilogram meter (kgf·m)	Joule (J)	1 kgf·m ≈ 9.8 J
Rate	Weight kilogram meter per second (kgf/m/s)	Watt (W)	1 kgf·m/s ≈ 9.8 W
Calorie	Calorie (cal)	Joule (J)	1 cal ≈ 4.2 J
Rotation	Rotation speed (rpm)	Rotation speed (r/min)	1 rpm = 1 r/min
Time	Second (sec) Minute (min) (reference) Hour (Hr) (reference)	Second (s) Minute (min) Hour (h)	1 sec = 1 s 1 min = 1 min 1 Hr = 1 h
Moment of inertia	GD^2 ($kgfm^2$)	Moment of inertia (kgm^2)	1 $kgfm^2$ = 0.25 kgm^2
Temperature	Degree (°C)	Degree Celsius (°C)	1°C = 1°C
Temperature difference	Degree (deg)	Degree Celsius (°C)	1 deg = 1°C
Weight	Weight kg (kgf)	Kilogram (kg)	1 kgf = 1 kg

For details other than the above, refer to ISO 1000.

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