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PROJECT EXERCISE 02 REPORT

Report Selection of a DC micromotor for the positioning system

HARSHIT VERMA
WARSAW UNIVERAITY OF TECHNOLOGY
Faculty of Mechatronics

1. Introduction

DC motors lack distinct regulated rotor positions, necessitating the use of position feedback devices for precise placement. This paper investigates a positioning system that employs an analogue position transducer, such as a precision potentiometer. The position signal from the motor is compared to the actual position measured by the transducer, and a non-zero differential signal, amplified by controllers such as proportional or PID, steers the motor until it reaches the prescribed position. Despite their complexity, DC motors are preferred for positioning drives due to benefits such as strong starting torque and linear control. The addition of a speed feedback loop improves dynamic qualities by adding damping to reduce oscillations or achieve the shortest positioning cycle.

2. Aim

The aim of the exercise is to learn the principles of selecting DC motors for dynamic applications and to acquire the ability to make such a selection on the example of a positioning system.

3. My data

No. of data set	J_{mech}	N	T_p
14	200	5	90

J_{mech} – mass moment of inertia of driven elements [gcm^2]

T_p - length of the positioning cycle [ms]

4. Motor selection algorithm

We need to select a motor based on given data and find out the remaining necessary information about it. Choosing a DC micromotor for placement entails determining how to move objects at a specific angle in a given amount of time. For tiny motions, we recommend a velocity profile, which is often triangular. The load in the case accelerates with constant acceleration and decelerates with a matching delay. The motor requires a constant current in its winding to maintain constant acceleration.

We have three values pre-decided for the gear ratios and we find calculate using the,

i_p= 2, 3, 4 ;

4.1. Determination of the angular acceleration

We first determine the angular acceleration of the required rotor, using the formula,

$$\mathcal{E}_a = \frac{\Delta\Upsilon}{\frac{1}{4}{T_p}^2} \qquad ...1$$

$\Delta\Upsilon$ - required angular displacement of the rotor. [deg]

$\mathcal{E}_a$ - angular acceleration of the rotor [rad/s^2]

In order to find $\mathcal{E}_a$, we need the values of $\Delta\Upsilon$.

After finding values for the $\Delta\Upsilon$ for gear ratios 2,3,4 respectively,

We find,

For i_p = 2	For i_p = 3	For i_p = 4
$\mathcal{E}_a = \frac{120}{\frac{1}{4}\cdot 0.09^2} = 59260\ \mathrm{deg/s^2} \approx 1039\ \mathrm{rad/s^2}$	$\mathcal{E}_a = \frac{180}{\frac{1}{4}\cdot 0.09^2} = 8888\ \mathrm{deg/s^2} \approx 1559\ \mathrm{rad/s^2}$	$\mathcal{E}_a = \frac{240}{\frac{1}{4}\cdot 0.09^2} = 118518\ \mathrm{deg/s^2} \approx 2079\ \mathrm{rad/s^2}$

4.1.1. Reduced rotation angle

We determine the reduced rotation angle of the required rotor, using the formula,

$$\Delta\Upsilon = \Delta\Upsilon_{mech}\, i_p \qquad ...2$$

We find,

For i_p = 2	For i_p = 3	For i_p = 4
$\Delta\Upsilon = 60^o \cdot 2 = 120^o$	$\Delta\Upsilon = 60^o \cdot 3 = 180^o$	$\Delta\Upsilon = 60^o \cdot 4 = 240^o$

$\Delta\Upsilon$ - required angular displacement of the rotor [deg]

$\Delta\Upsilon_{mech}$ - required angular displacement of the mechanism [deg]

i_p – gear ratio [1]

4.2. Determination of the driving torque

We find the driving torque required to drive the load, We assume $J_{red} = J_S$, since, our value lies within the same range,

Using the formula,

$$M_a = \mathcal{E}_a(J_{red} + J_s) \qquad ...3$$

For i_p = 2	For i_p = 2	For i_p = 2
$M_a = 1039(55.55 + 55.55) = 115{,}432.9 \text{ rad g}\frac{cm^2}{s^2} \approx 10mNm$	$M_a = 1559(24.69 + 24.69) = 76{,}983.42 \text{ rad g}\frac{cm^2}{s^2} \approx 8 \text{ mNm}$	$M_a = 2079(13.88 + 13.88) = 57{,}713.04 \text{ rad g}\frac{cm^2}{s^2} \approx 6 \text{ mNm}$

M_a – required motor torque [mNm]

J_{red} – reduced mass moment of inertia of load [gcm^2]

J_s – rotor mass moment of inertia [gcm^2]

4.2.1. Reduced inertial load

We find the reduced inertial load,

We assume η_p = 0,9,

Using the formula,

$$J_{red} = \frac{J_{mech}}{\eta_p {i_p}^2} \qquad ...4$$

For i_p = 2	For i_p = 3	For i_p = 4
$J_{red} = \frac{200}{0.9 \cdot 2^2} = 55.55 \text{ g cm}^2$	$J_{red} = \frac{200}{0.9 \cdot 3^2} = 24.69 \text{ g cm}^2$	$J_{red} = \frac{200}{0.9 \cdot 4^2} = 13.88 \text{ g cm}^2$

J_{mech} - mass moment of inertia of driven elements [gcm^2]

J_{red}- reduced mass moment of inertia of the load [gm^2]

i_p - gear ratio [1]

η_p - efficiency of the transmission [1]

4.3. Motor selection

We have all the values to decide upon the motors, we select for each set of gear ratio,

After relating the values of torque and speed in the graph, we select the motor 12G88 with 2.5 Watt, motor 13N88 with 2.5 Watt and motor 16C18 with 0.85 Watt.

For i_p = 2	For i_p = 3	For i_p = 4
Motor - 22N78/98/324P	Motor - 22N28/48/-216P	Motor - 22V28/48/-213P

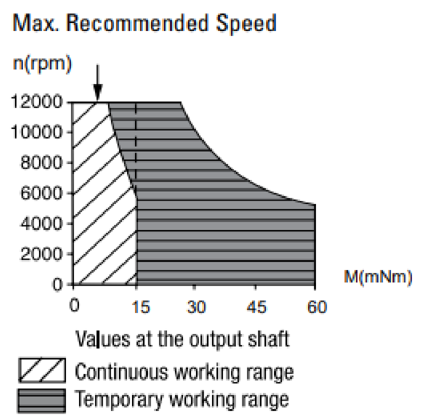


FIGURE 4.3-1 (MAX CONTINUOUS TORQUE VS MAX RPM FOR MOTOR 22N78)

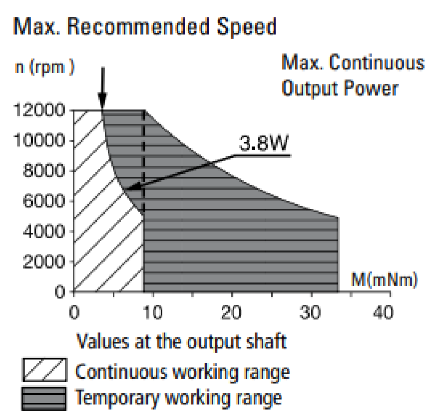


FIGURE 4.3-2(MAX CONTINUOUS TORQUE VS MAX RPM FOR MOTOR 22N28/48)

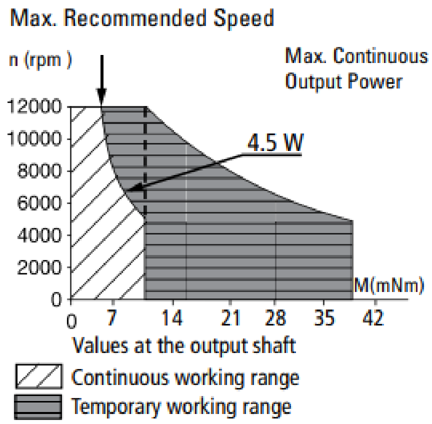


FIGURE 4.3-3(MAX CONTINUOUS TORQUE VS MAX RPM FOR MOTOR 22V28)

TABLE 1(TABLE FOR MOTOR - 22N78)

Winding Type	⊙⊙	324P	319P	313P	311P	216E	215E	208E
Measured Values								
Measuring voltage	V	3	6	9	12	18	24	48
No-load speed	rpm	6400	8700	6800	7300	8200	9100	6400
Stall torque	mNm	52.0	66.0	45.0	48.0	49.0	58.0	32.0
Average No-load current	mA	15	10	10	7	6	5	1
Typical starting voltage	V	0.05	0.1	0.1	0.15	0.2	0.3	0.5
Max. Recomended Values								
Max. continuous current	A	3.7	2.4	1.18	0.98	0.67	0.58	0.18
Max. continuous torque	mNm	16.5	15.7	14.6	14.8	13.8	14.5	12.9
Max. angular acceleration	10^3 rad/s^2	120	130	133	141	117	128	157
Intrinsic Parameters								
Back-EMF constant	V/1000 rpm	0.47	0.69	1.31	1.64	2.18	2.64	7.50
Torque constant	mNm/A	4.5	6.6	12.5	15.8	20.8	25.2	72.0
Terminal resistance	Ohms	0.3	0.6	2.5	3.9	7.7	10.5	107.0
Motor regulation R/k^2	10^3/Nms	13	14	16	16	18	17	21
Rotor inductance	mH	0.02	0.04	0.16	0.25	0.50	0.70	7.00
Rotor inertia	kgm^2 10^{-7}	5.45	4.90	4.39	4.20	4.74	4.50	3.32
Mechanical time constant	ms	7.0	6.8	7.0	6.7	8.4	7.4	6.9

TABLE 2(TABLE FOR MOTOR - 22N28)

Winding Type	⊙⊙	-216P	-216E	-213E	-210E	-208E	-105
Measured Values							
Measuring voltage	V	3.0	6.0	9.0	12.0	18.0	18.0
No-load speed	rpm	5200	5600	7000	5900	6300	3600
Stall torque	mNm (oz-in)	10.9 (1.54)	10.6 (1.50)	10.7 (1.51)	8.6 (1.21)	8.2 (1.16)	4.3 (0.61)
Average No-load current 1)	mA	12.6/27	7.0/14	6.0/11	4.5/9	3.5/7	1.4/3
Typical starting voltage 1)	V	0.03/0.25	0.05/0.35	0.06/0.45	0.08/0.5	0.12/0.7	0.24/0.90
Max. Recommended Values							
Max. continuous current	A	1.50	0.83	0.62	0.38	0.26	0.14
Max. continuous torque	mNm (oz-in)	8.1 (1.15)	8.4 (1.19)	7.5 (1.06)	7.3 (1.04)	7.0 (0.98)	6.6 (0.93)
Max. angular acceleration	10^3 rad/s^2	100	96	107	98	96	132
Intrinsic Parameters							
Back-EMF constant	V/1000 rpm	0.57	1.07	1.28	2.02	2.83	4.95
Torque constant	mNm/A (oz-in/A)	5.44 (0.77)	10.2 (1.45)	12.2 (1.73)	19.3 (2.73)	27.0 (3.83)	47.3 (6.69)
Terminal resistance	ohm	1.50	5.80	10.3	27.0	59.0	200
Motor regulation R/k^2	10^3/Nms	51	56	69	73	81	90
Rotor inductance	mH	0.10	0.35	0.50	1.20	2.30	7.00
Rotor inertia	kgm^2 10^{-7}	3.50	3.50	2.80	3.00	2.90	2.00
Mechanical time constant	ms	18	19	19	22	23	18

TABLE 3(TABLE FOR MOTOR - 22V28)

Winding Type	⊙⊙	-213P	-216E	-213E	-210E	-208E
Measured Values						
Measuring voltage	V	6.0	9.0	12.0	15.0	24.0
No-load speed	rpm	7100	6700	7600	7500	6300
Stall torque	mNm (oz-in)	16.0 (2.27)	17.1 (2.42)	15.0 (2.13)	11.5 (1.63)	11.5 (1.62)
Average No-load current 1)	mA	15/22	9/13.5	7.6/11	6.0/9	3.2/4.8
Typical starting voltage 1)	V	0.08/0.3	0.10/0.4	0.15/0.6	0.24/1.0	0.4/1.6
Max. Recommended Values						
Max. continuous current	A	1.15	0.77	0.58	0.40	0.23
Max. continuous torque	mNm (oz-in)	9.09 (1.29)	9.66 (1.37)	8.48 (1.20)	7.4 (1.05)	8.13 (1.15)
Max. angular acceleration	10^3 rad/s^2	113	99	105	102	134
Intrinsic Parameters						
Back-EMF constant	V/1000 rpm	0.84	1.33	1.56	1.97	3.75
Torque constant	mNm/A (oz-in/A)	8.0 (1.13)	12.7 (1.80)	14.9 (2.11)	18.8 (2.66)	35,8 (5.07)
Terminal resistance	ohm	3.00	6.70	11.9	24.5	75.0
Motor regulation R/k^2	10^3/Nms	47	42	54	69	58
Rotor inductance	mH	0.15	0.50	0.55	0.80	3.30
Rotor inertia	kgm^2 10^{-7}	3.20	3.90	3.20	2.90	2.40
Mechanical time constant	ms	15	16	17	20	14

4.4. Determination of the motor current

We find the control current on the basis of the knowledge of the motor torque constant, using the formula,

$$i_a = \frac{M_a}{K_T} \qquad \ldots 5$$

K_T - torque constant [mNm/A]

M_a - required motor torque [mNm]

i_a - motor current [A]

We find,

For i_p = 2	For i_p = 3	For i_p = 4
$i_a = \frac{10}{4.5} = 2.2\ \mathrm{A}$	$i_a = \frac{8}{5.44} = 1.48\ \mathrm{A}$	$i_a = \frac{6}{8} = 0.75\ \mathrm{A}$

4.5. Determination of rotor temperature

$$T_W = \frac{R_o i_a R_{wot}(1 - T_o \alpha_{cu}) + T_{ot}}{1 - \alpha_{cu} R_o {i_a}^2 R_{wot}} \quad ...6$$

We observe that the T_W value is significantly higher than the ambient temperature and do not exceed the permissible temperature., i.e. 343.15 K.

$$R_{wot} = R_{ws} + R_{so} \quad ...7$$

For i_p = 2	For i_p = 3	For i_p = 4
$R_{wot} = 0.3 + 28 = 28.3\ \mathrm{K/W}$	$R_{wot} = 1.5 + 28 = 29.5\ \mathrm{K/W}$	$R_{wot} = 3 + 28 = 31\ \mathrm{K/W}$

α_{cu} - temp. coefficient of copper resistivity [1]

i_a - motor current [A]

R_o - terminal resistance in T0 temperature [Ω]

R_{ws} - thermal resistance rotor-body [K/W]

R_{so} - thermal resistance body-ambient [K/W]

T_o - reference temperature [K]

T_W - rotor temperature [K]

Ts - stator temperature [K]

T_{ot} - ambient temperature [K]

4.6. Calculation of the rotor resistance

We find the rotor resistance R_t at temperature T_w, using the formula,

$$R_t = R_o[1 + (T_w - T_o)\alpha_{cu}] \quad ...8$$

For i_p = 2	For i_p = 3	For i_p = 4
$R_t = 3.2 \cdot [1 + (332.67 - 295.15) \cdot 0.0039] = 4.02\ \Omega$	$R_t = 4.2 \cdot [1 + (332.32 - 295.15) \cdot 0.0039] = 4.89\ \Omega$	$R_t = 1.2 \cdot [1 + (348.83 - 295.15) \cdot 0.0039] = 1.58\ \Omega$

R_t - instantaneous armature resistance [Ω]

R_o - armature circuit resistance at T_o [Ω]

T_o - reference temperature [K]

T_w - rotor temperaturę [K]

α_{cu} - temperature coefficient of copper resistivity [1]

4.7. Determination of the maximum motor speed

We calculate the maximum motor speed, using the formula,

$$\omega_m = \frac{1}{2} T_p \mathcal{E}_a \quad ...9$$

For i_p = 2	For i_p = 3	For i_p = 4
$\omega_m = \frac{0.09 \cdot 1039}{2} = 46.75\ \mathrm{rad/s}$	$\omega_m = \frac{0.09 \cdot 1559}{2} = 70.15\ \mathrm{rad/s}$	$\omega_m = \frac{0.09 \cdot 2079}{2} = 93.55\ \mathrm{rad/s}$

T_p – duration of the positioning cycle [s]

$\mathcal{E}_a$ – angular acceleration of the rotor [rad/s^2]

ω_m – maximum angular speed of the rotor [rad/s]

4.8. Determination of the control voltage

We find the control voltage needed to control the motor, using the voltage,

$$U_{min} = R_t i_a + K_E \omega_m \quad \text{...10}$$

For i_p = 2	For i_p = 3	For i_p = 4
$U_{min} = 4.02 \cdot 0.204 + 0.51 \cdot 46.75 = 24.60\ \mathrm{V}$	$U_{min} = 4.89 \cdot 0.174 + 0.48 \cdot 70.15 = 34.55\ \mathrm{V}$	$U_{min} = 1.58 \cdot 0.681 + 0.092 \cdot 93.55 = 9.59\ \mathrm{V}$

K_E - back EMF constant [V/rad/s]

i_a - motor current [A]

R_t - terminal resistance [Ω]

U_{min} - minimum control voltage [V]

ω_m - maximum angular speed of the rotor [rad/s]

5.Conclusions:

- **The method used to select the motors that meets specific requirements, and a transmission is quick and simple.**
- **The selected motors meet the specific requirements.**
- **The selected motors are for three gear ratios.**

6. Literature:

a. **MDR_2022 - Proj_Ex_2 – Instruction by J. Wierciak.**
b. **MDR_2022 - Proj_Ex_2 - Portescap catalogue**

7. Attachments:

a. **Catalogue card of the selected motor -** 22N78/98**.**
b. **Catalogue card of the selected motor -** 22N28/48**.**
c. **Catalogue card of the selected motor -** 22V28/48**.**

Declaration of Work

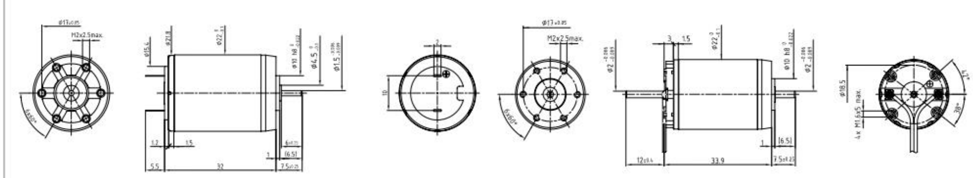
I, Harshit Verma, confirm that the work for the following term paper with the title: "PROJECT EXERCISE 02 Report - Selection of a DC micromotor for the positioning system" was solely undertaken by myself and that no help was provided from other sources as those allowed. All sections of the paper that use quotes or describe an argument or concept developed by another author have been referenced, including all secondary literature used, to show that this material has been adopted to support my thesis.

Harshit Verma Warsaw,
Poland
302601
17/02/23

9 Watt

Precious Metal Commutation System - 9 Segments

Max traction force: 300 N
Max screw torque: 130 mNm



dimensions in mm
mass: 53 g

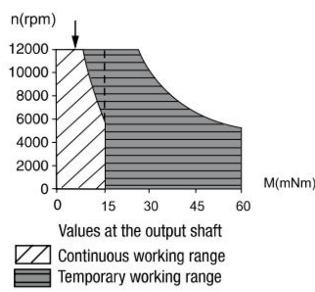
22N78 ⊙⊙ • 1001 **22N98 ⊙⊙ • 1005**

Winding Type	⊙⊙	324P	319P	313P	311P	216E	215E	208E
Measured Values								
Measuring voltage	V	3	6	9	12	18	24	48
No-load speed	rpm	6400	8700	6800	7300	8200	9100	6400
Stall torque	mNm	52.0	66.0	45.0	48.0	49.0	58.0	32.0
Average No-load current	mA	15	10	10	7	6	5	1
Typical starting voltage	V	0.05	0.1	0.1	0.15	0.2	0.3	0.5
Max. Recomended Values								
Max. continuous current	A	3.7	2.4	1.18	0.98	0.67	0.58	0.18
Max. continuous torque	mNm	16.5	15.7	14.6	14.8	13.8	14.5	12.9
Max. angular acceleration	10^3 rad/s²	120	130	133	141	117	128	157
Intrinsic Parameters								
Back-EMF constant	V/1000 rpm	0.47	0.69	1.31	1.64	2.18	2.64	7.50
Torque constant	mNm/A	4.5	6.6	12.5	15.8	20.8	25.2	72.0
Terminal resistance	Ohms	0.3	0.6	2.5	3.9	7.7	10.5	107.0
Motor regulation R/k²	10^3/Nms	13	14	16	16	18	17	21
Rotor inductance	mH	0.02	0.04	0.16	0.25	0.50	0.70	7.00
Rotor inertia	kgm^2 10^{-7}	5.45	4.90	4.39	4.20	4.74	4.50	3.32
Mechanical time constant	ms	7.0	6.8	7.0	6.7	8.4	7.4	6.9

Executions				
		Single Shaft	**With MR2**	**With E9**
Gearbox	**Page**	**22N78**	**22N98**	**22N98**
R22	**239**	**1001**	**1008**	**1005**
M22	**240**	**1001**	**1008**	**1005**
K24	**241**	**1001**	**1008**	**1005**
K27	**242**	**1001**	**1008**	**1005**
RG1/8	**245**	**1007**	**1009**	**1006**
RG1/9	**246**	**1007**	**1009**	**1006**
K38	**244**	**1007**	**1009**	**1006**

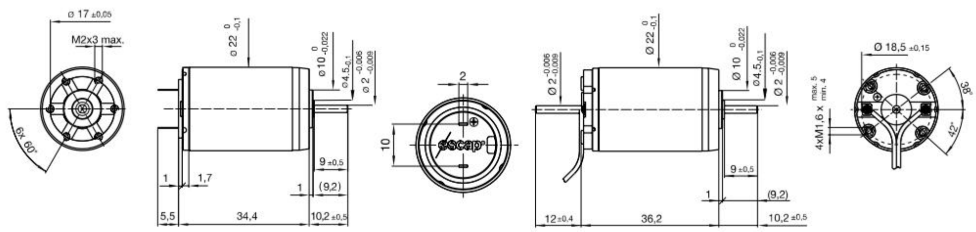
- Thermal resistance :
  rotor-body 6°C/W
  body-ambient 22°C/W
- Thermal time constant –
  rotor/stator: 9s / 550s
- Max. rated coil temperature:
  100°C (210°F)
- Recom. Ambient temperature
  range: -30°C to +65°C (-22°F to +150°F)
- Viscous damping constant:
  0.1×10^{-6} Nms
- Max axial static force for press-fit:
  150N (with sleeve bearing only)
- End play: ≤ 150 µm
  Radial play: ≤ 30 µm
  Shaft runout: ≤10 µm
- Max. side load at 5mm from
  mounting face – sleeve bearings 3 N
  – ball bearings 6 N
- Motor fitted with sleeve bearings
  (ball bearings optional)

Max. Recommended Speed



Precious Metal Commutation System - 9 Segments — 4.5 Watt

Max screw torque 130 mNm
Max traction 300N



dimensions in mm
mass: 68 g

22V28 ⊙⊙ • 201 — **22V48 ⊙⊙ • 204**

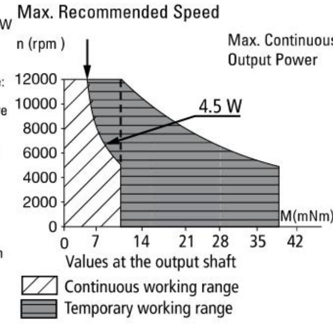
Winding Type	**⊙⊙**	**-213P**	**-216E**	**-213E**	**-210E**	**-208E**
Measured Values						
Measuring voltage	V	6.0	9.0	12.0	15.0	24.0
No-load speed	rpm	7100	6700	7600	7500	6300
Stall torque	mNm (oz-in)	16.0 (2.27)	17.1 (2.42)	15.0 (2.13)	11.5 (1.63)	11.5 (1.62)
Average No-load current 1)	mA	15/22	9/13.5	7.6/11	6.0/9	3.2/4.8
Typical starting voltage 1)	V	0.08/0.3	0.10/0.4	0.15/0.6	0.24/1.0	0.4/1.6
Max. Recommended Values						
Max. continuous current	A	1.15	0.77	0.58	0.40	0.23
Max. continuous torque	mNm (oz-in)	9.09 (1.29)	9.66 (1.37)	8.48 (1.20)	7.4 (1.05)	8.13 (1.15)
Max. angular acceleration	10^3 rad/s^2	113	99	105	102	134
Intrinsic Parameters						
Back-EMF constant	V/1000 rpm	0.84	1.33	1.56	1.97	3.75
Torque constant	mNm/A (oz-in/A)	8.0 (1.13)	12.7 (1.80)	14.9 (2.11)	18.8 (2.66)	35,8 (5.07)
Terminal resistance	ohm	3.00	6.70	11.9	24.5	75.0
Motor regulation R/k²	10^3/Nms	47	42	54	69	58
Rotor inductance	mH	0.15	0.50	0.55	0.80	3.30
Rotor inertia	kgm² 10^{-7}	3.20	3.90	3.20	2.90	2.40
Mechanical time constant	ms	15	16	17	20	14

1) Single Shaft/double shaft

		Executions		
		Single Shaft	**For F16**	**For E9**
Gearbox	**Page**	**22V28**	**22V28**	**22V48**
R22	**239**	**202**	**202**	**225**
M22	**240**	**201**	**201**	**204**
K24	**241**	**202**	**202**	**225**
K27	**242**	**202**	**202**	**225**
RG1/8	**245**	**201**	**201**	**204**
RG1/9	**246**	**201**	**201**	**204**
K38	**244**	**201**	**201**	**204**

- Thermal resistance: rotor-body 6°C/W, body-ambient 22°C/W
- Thermal time constant - rotor / stator: 10 s / 460 s
- Max. rated coil temperature: 100°C (210°F)
- Recom. ambient temperature range: -30°C to +85°C (-22°F to +185°F)
- Viscous damping constant: 0.1 x 10-6 Nms
- Max. axial static force for press-fit: 150 N
- End play: ≤ 150 µm
  Radial play: ≤ 30 µm
  Shaft runout: ≤ 10 µm
- Max. side load at 5 mm from mounting face:
  - sleeve bearings 3 N
  - ball bearings 6 N
- Motor fitted with sleeve bearings (ball bearings optional)

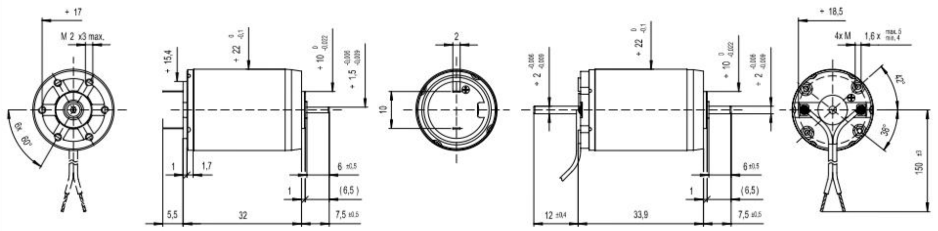
Max. Recommended Speed



3.8 Watt

Precious Metal Commutation System - 9 Segments

Max screw torque 130 mNm
Max traction 300N



dimensions in mm
mass: 53 g

22N28 ⊙⊙ • 286

22N48 ⊙⊙ • 308

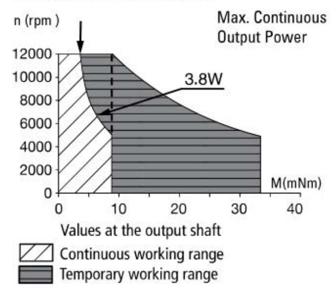
Winding Type	⊙⊙	**-216P**	**-216E**	**-213E**	**-210E**	**-208E**	**-105**
Measured Values							
Measuring voltage	V	3.0	6.0	9.0	12.0	18.0	18.0
No-load speed	rpm	5200	5600	7000	5900	6300	3600
Stall torque	mNm (oz-in)	10.9 (1.54)	10.6 (1.50)	10.7 (1.51)	8.6 (1.21)	8.2 (1.16)	4.3 (0.61)
Average No-load current 1)	mA	12.6/27	7.0/14	6.0/11	4.5/9	3.5/7	1.4/3
Typical starting voltage 1)	V	0.03/0.25	0.05/0.35	0.06/0.45	0.08/0.5	0.12/0.7	0.24/0.90
Max. Recommended Values							
Max. continuous current	A	1.50	0.83	0.62	0.38	0.26	0.14
Max. continuous torque	mNm (oz-in)	8.1 (1.15)	8.4 (1.19)	7.5 (1.06)	7.3 (1.04)	7.0 (0.98)	6.6 (0.93)
Max. angular acceleration	10^3 rad/s²	100	96	107	98	96	132
Intrinsic Parameters							
Back-EMF constant	V/1000 rpm	0.57	1.07	1.28	2.02	2.83	4.95
Torque constant	mNm/A (oz-in/A)	5.44 (0.77)	10.2 (1.45)	12.2 (1.73)	19.3 (2.73)	27.0 (3.83)	47.3 (6.69)
Terminal resistance	ohm	1.50	5.80	10.3	27.0	59.0	200
Motor regulation R/k²	10^3/Nms	51	56	69	73	81	90
Rotor inductance	mH	0.10	0.35	0.50	1.20	2.30	7.00
Rotor inertia	kgm² 10^{-7}	3.50	3.50	2.80	3.00	2.90	2.00
Mechanical time constant	ms	18	19	19	22	23	18

1) Single Shaft/double shaft

		Executions		
		Single Shaft	**For F16**	**For E9**
Gearbox	**Page**	**22N28**	**22N28**	**22N48**
R22	**239**	**286**	**286**	**308**
M22	**240**	**286**	**286**	**308**
K24	**241**	**286**	**286**	**308**
K27	**242**	**286**	**286**	**308**
RG1/8	**245**	**204**	**204**	**310**
RG1/9	**246**	**204**	**204**	**310**
K38	**244**	**204**	**204**	**310**

- Thermal resistance: rotor-body 6°C/W body-ambient 22°C/W
- Thermal time constant - rotor / stator: 9 s / 550 s
- Max. rated coil temperature: 100°C (210°F)
- Recom. ambient temperature range: -30°C to +65°C (-22°F to +150°F)
- Viscous damping constant: 0.1 x 10-6 Nms
- Max. axial static force for press-fit: 150 N
- End play: ≤ 150 µm Radial play: ≤ 30 µm Shaft runout: ≤ 10 µm
- Max. side load at 5 mm from mounting face:
  - sleeve bearings 3 N
  - ball bearings 6 N
- Motor fitted with sleeve (ball bearings optional)

Max. Recommended Speed



Brushed DC