DECEMBER 4, 2023

PROJECT EXERCISE 01 Report

SELECTION OF A DC MICRO MOTOR WITH GEAR FOR STEADY-STATE OPERATION

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1. Introduction

Designers of drive systems frequently encounter a dilemma in which motors with sufficient power to drive the mechanism produce insufficient torques on the rotor shaft while developing excessive rotational speeds. Traditionally, reduction gears are employed in such cases, preferably among those approved by the vehicle's manufacturer.

2. Aim

The aim of the exercise is to learn the principles of selecting a DC drive motor with a gearbox for static operation and to acquire the ability to independently carry out such a selection.

3. My Data:

Topic No.	M_{mech} [Nm]	n_{mech} [rpm]	T_{ot} [$°C$]
14	1	60	20

M_{mech} – torque required to drive the mechanism

n_{mech} – required rotational speed at the input of the mechanism

$T_{ot} - ambient\ tempera$ture

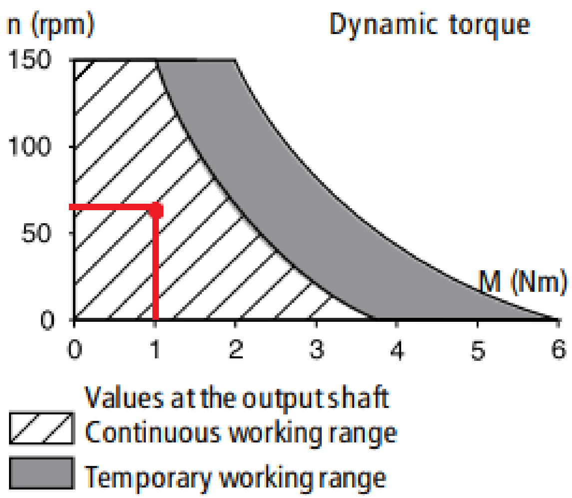
4. Motor and transmission selection

When designing a geared drive, the designer usually knows the torque M_{mech} needed to drive the mechanism and the speed n_{mech} required at the input of the mechanism. Additionally, there is often a sure limitation in the form of the maximum supply voltage Uz_{max}.

4.1. Gear selection

We select a gear unit from the catalogue that can be continuously loaded with M_{mech} torque.

We can observe in the graph of dynamic torque and relate M_{mech} and n_{mech}.



The Gearhead that allows M_{mech} [Nm] = 1, n_{mech} [rpm] = 60 is **K40**.

4.1.1 Determination of the gear ratio

$$n_{max} = 4000\, rpm$$

$$ig_{max} = \frac{n_{max}}{n_{mech}} = \frac{4000 \text{ rpm}}{60\, rpm} = 66.66$$

$n_{max} - maximm\ allowable\ speed\ of\ input\ gear\ shift$

$ig_{max} - maximum\ gear\ ratio$

4.1.2 Gear selection

We select the catalogue gear ratio not higher than the calculated one.

$$i_p \leq ig_{max}$$

From the catalogue, we observe that the value most suited is 60.

Ratio	⊙⊙	5	10	15	20	30	45	$\boxed{60}$	90
No. of gear stages		2	3	3	4	4	4	5	5

Therefore, $i_g = 60$

4.2 Determination of reduced loads

We read the efficiency n_{mech} of the gear, then calculate the reduced torque loading the motor using formula: $M_{red} = \frac{M_{mech}}{n_g \cdot i_g}$

Ratio ⊙⊙	5	10	15	20	30	45	60	90	135	180	270	405
No. of gear stages	2	3	3	4	4	4	5	5	5	6	6	6
Direction of Rotation	=	≠	≠	=	=	=	≠	≠	≠	=	=	=
Efficiency	0.8	0.7	0.7	0.65	0.65	0.65	0.6	0.6	0.6	0.55	0.55	0.55
L (mm)	40	40	40	50	50	50	50	50	50	50	50	50
Mass (g)	120	125	125	145	145	145	150	150	150	155	155	155

We observe that the efficiency for the selected values is 0.6.

$$M_{red} = \frac{1\ Nm}{0.6 \cdot 60}$$

$$M_{red} = 0.027\ Nm$$

$$M_{red} = 27.77\ mNm$$

We calculate reduced motor speed n_{red},

$$n_{red} = n_{mech} \cdot i_g$$

$$n_{red} = 60\ rpm \cdot 60$$

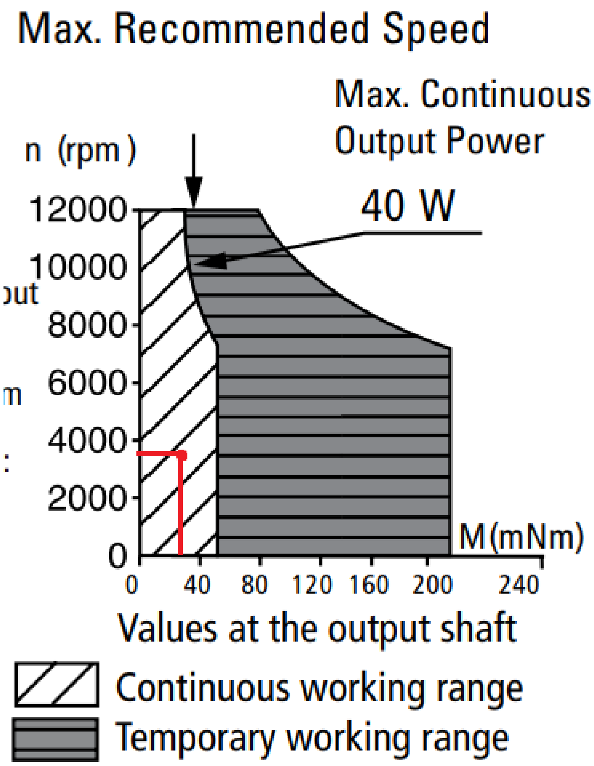
$$n_{red} = 3600\ rpm$$

i_g – *selected gear ratio*

n_{red} – *speed reduced to the motor shaft*

M_{red} – *torque reduced to the motor shaft*

4.3 Motor selection



We find the required value by relating M_{red} and n_{red}.

Since our values lie in the safe region, we selected motor **25GT2R82**.

Winding Type	⊙⊙	-222E	-222P	-219P	-219E
Measured Values					
Measuring voltage	V	15	18	24	36
No-load speed	rpm	4130	9500	10300	8300
Stall torque	mNm (oz-in)	129 (18.3)	249 (35)	258 (37)	200(28)
Average No-load current 1)	mA	30	140	120	65
Typical starting voltage 1)	V	--	--	--	--
Max. Recommended Values					
Max. continuous current	A	1.44	2.5	2	1.06
Max. continuous torque	mNm (oz-in)	48 (6.8)	42 (5.9)	41 (5.8)	41 (5.8)
Max. angular acceleration	10^3 rad/s²	186	165	160	157
Intrinsic Parameters					
Back-EMF constant	V/1000 rpm	3.6	1.88	2.3	4.3
Torque constant	mNm/A (oz-in/A)	34.4 (4.87)	18 (2.54)	22 (3.11)	41.1 (5.89)
Terminal resistance	ohm	4.2	1.3	2.05	7.4
Motor regulation R/k²	10^3/Nms	3.4	4	4.2	4.4
Rotor inductance	mH	0.3	0.08	0.14	0.5
Rotor inertia	kgm² 10^{-7}	13	13	13	13
Mechanical time constant	ms	4.4	5.2	5.5	5.7

4.4 Determination of motor current

The current I consumed by the motor loaded with the moment M_{red} is calculated using the formula:

$$I = \frac{M_{red}}{K_T}$$

We select a value for K_T, In my case, I chose 41.1 mNm/A

$$I = \frac{27.77}{41.1}$$

$$I = 0.675\ A$$

$I - motor\ current[A]$

$K_T - torque\ constant[Nmm/A]$

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Rotor inertia	kgm^2 10^{-7}	13	13	13	13
Mechanical time constant	ms	4.4	5.2	5.5	5.7

4.5 Determination of supply voltage

Calculate the supply voltage needed to drive the mechanism at the reference temperature T0 of the motor parameters. This temperature, specified in the catalogue, is usually 20 ˚C or 22 ˚C. According to the equation of voltage equilibrium in a DC motor: $U_Z = R_o \cdot I + K_E \cdot n_{red}$

In our case, Back EMF, K_E= 4.3 V/1000rpm

And, Terminal resistance, R_o= 7.4 Ω

$$U_Z = 7.4\ \Omega \cdot 0.675\ A + 4.3\ \text{V/1000rpm} \cdot 3600\ rpm$$

$$U_Z = 20.47\ V$$

$K_E - Back\ EMF\ constant$

$R_o - terminal\ resistance$

U_Z – supply voltage

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4.6 Checking the thermal condition of the motor

We check whether the steady winding temperature does not exceed the permissible value.

We get the steady rotor temperature:

$$T_W = \frac{R_O \cdot I^2 \cdot R_{th} \cdot (1 - T_o \cdot a) + T_{ot}}{1 - a \cdot R_o \cdot I^2 \cdot R_{th}}$$

We find R_{th}:

$$R_{th} = R_{ws} + R_{sot}$$

$$R_{th} = 11\ \frac{°C}{W} + 5\frac{°C}{W}$$

$$R_{th} = 16\ °C/W$$

And in our case, thermal coefficient of winding resistivity, $\alpha = 0.0039°C^{-1}$

R_O − *resistance of winding in* T_o *temperature*

T_o − *reference temperature*

a − *thermal coeffient of winding resistivity*

T_{ot} − *ambient temperature*

Now,

$$T_W = \frac{7.4\,\Omega \cdot 0.675\,A^2 \cdot 16\,°C/W \cdot (1 - 20°C \cdot 0.0039°C^{-1}) + 20^0 C}{1 - 0.0039°C^{-1} \cdot 7.4\,\Omega \cdot 0.675\,A^2 \cdot 16\,°C/W}$$

$$T_W = 88\,°C$$

Since our calculated rotor temperature T_W is lower than the permissible value due to the winding insulation given in the catalogue, the selection of the motor and gearbox can be considered as completed.

- Thermal resistance:
  rotor-body 5°C/W
  body-ambient 11°C/W
- Thermal time constant - rotor / stator:
  10 s / 450 s
- Max. rated coil temperature: 155°C
- Recom. ambient temperature range:
  -30°C to +125°C (-22°F to +257°F)
- Max. axial static force for press-fitted without holding shaft (sleeve/ball b.) 500 N / 100N
- Axial/radial play (ball bearings) neglectable
- Max axial/radial play (sleeve b.) 150µm/30µm
- Shaft runout: ≤ 10 µm
- Max. side load at 5 mm from mounting face:
  - sleeve bearings 8 N
  - ball bearings 25 N
- Motor fitted with ball bearings
  (sleeve bearings optional)
- 83 Communication is recommended
  for servo applications

now we must recalculate the supply voltage for the changed value of the winding electrical resistance: $U_Z = R_t \cdot I + K_E \cdot n_{red}$

but first we must find, $R_t = R_o \cdot [1 + (T_W - T_o) \cdot a]$

$$R_t = 7.4\ \Omega \cdot [1 + (88°\mathrm{C} - 20°\mathrm{C}) \cdot 0.0039°\mathrm{C}^{-1}]$$

$$R_t = 1.26\ \Omega$$

Now, $U_Z = 1.26\ \Omega \cdot 0.675\ A + 4.3 \frac{\mathrm{V}}{1000\mathrm{rpm}} \cdot 3600\ rpm$

$$U_Z = 16.33\ \mathrm{V}$$

5. Conclusions:

- The method used to select an engine that meets specific requirements, and a transmission is quick and simple.
- The selected engine and transmission meet all the requirements and can be used to perform the required task.
- The operating point of both the motor and the gearbox is in the continuous operation area of the characteristic. The motor operates with lower than nominal voltage, the current consumed does not exceed the maximum value specified by the manufacturer. The motor winding temperature does not exceed the value specified by the manufacturer.
- The selected engine achieves very good efficiency.

6. Literature:

6.1. MDR_2022 - Proj_Ex_1 – Instruction by J. Wierciak.
6.2. MDR_2022 - Proj_Ex_1 - Portescap catalogue

7. Attachments:

7.1. Catalogue card of the selected gearhead - **K40.**
7.2. Catalogue card of the selected motor - **25GT2R82.**

Declaration of Work

I, Harshit Verma, confirm that the work for the following term paper with the title: "PROJECT EXERCISE 01 Report - Selection of a DC micromotor with gear for steady-state operation" 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.

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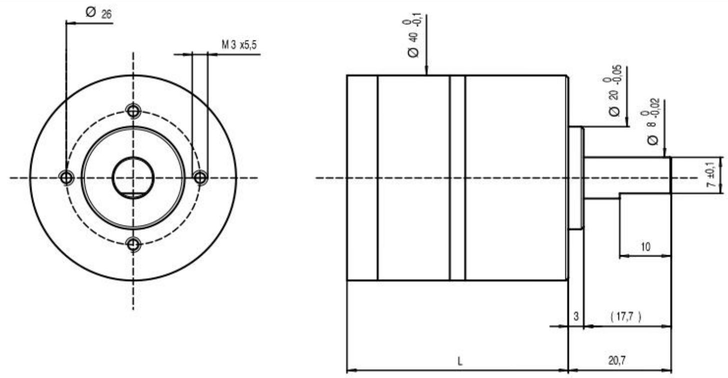
12/02/23

Portescap
A Danaher Motion Company

K40

Reduction Gearhead with Spur Gears — 3 Nm

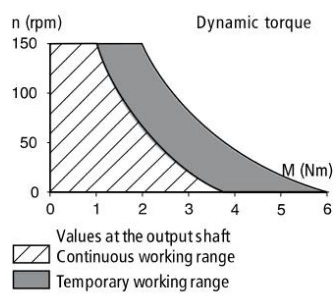


dimensions in mm

K40 • 100 ⊙⊙

Ratio ⊙⊙	5	10	15	20	30	45	60	90	135	180	270	405
No. of gear stages	2	3	3	4	4	4	5	5	5	6	6	6
Direction of Rotation	=	≠	≠	=	=	=	≠	≠	≠	=	=	=
Efficiency	0.8	0.7	0.7	0.65	0.65	0.65	0.6	0.6	0.6	0.55	0.55	0.55
L (mm)	40	40	40	50	50	50	50	50	50	50	50	50
Mass (g)	120	125	125	145	145	145	150	150	150	155	155	155
Available with motor												
25GT2R82 • 6 / 8												
28LT12 • 49 / 316												
28L28 • 49 / 315												
28D11 • 4												
35NT2R32 • 54 / 66												

Characteristics		K40 • 100	K40 2R • 100
Bearing Type		sleeve	ball
Max. static torque	Nm (oz-in)	6 (850)	6 (850)
Max. radial force at 8 mm from mounting face	N (lb)	80 (18)	150 (33.75)
Max. axial force	N (lb)	80 (18)	150 (33.75)
Force for press-fit	N (lb)	200 (45)	200 (45)
Average backlash at no-load		1°	1°
Average backlash at 0.3 Nm		1.5°	1.5°
Radial play	µm	≤50	≤10
Axial play	µm	50-250	≤10
Max. recom. input speed	rpm	4000	4000
Operating temperature range	°C (°F)	-30...+65 (-22...+150)	



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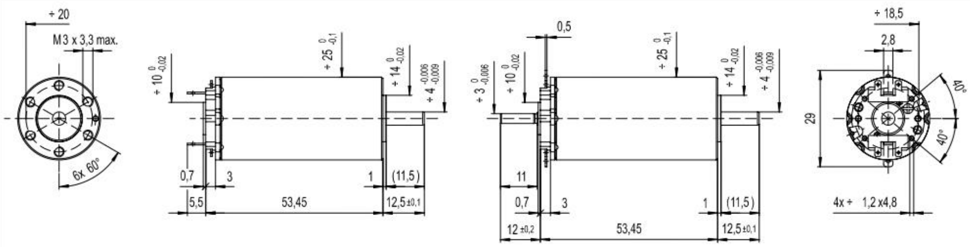
Portescap
A Danaher Motion Company

25GT2R82

Graphite/Copper Communication System - 9 Segments — 40 Watt



dimensions in mm
mass: 145 g

25GT2R82 ⊙⊙ • 1 — **25GT2R82 ⊙⊙ • 2**

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Rotor inertia	kgm² 10^{-7}	13	13	13	13
Mechanical time constant	ms	4.4	5.2	5.5	5.7

1) Single Shaft/double shaft

		Executions		
		Single Shaft	**For E9**	**HED5**
Gearbox	**Page**	**25GT2R82**	**25GT2R82**	**25GT2R82**
K40	**247**	**6**	**8**	**--**
R32	**243**	**6**	**8**	**--**
R40	**248**	**1**	**2**	**4**

- Thermal resistance:
  rotor-body 5°C/W
  body-ambient 11°C/W
- Thermal time constant - rotor / stator:
  10 s / 450 s
- Max. rated coil temperature: 155°C
- Recom. ambient temperature range:
  -30°C to +125°C (-22°F to +257°F)
- Max. axial static force for press-fitted without holding shaft (sleeve/ball b.) 500 N / 100N
- Axial/radial play (ball bearings) neglectable
- Max axial/radial play (sleeve b.) 150µm/30µm
- Shaft runout: ≤ 10 µm
- Max. side load at 5 mm from mounting face:
  - sleeve bearings 8 N
  - ball bearings 25 N
- Motor fitted with ball bearings (sleeve bearings optional)
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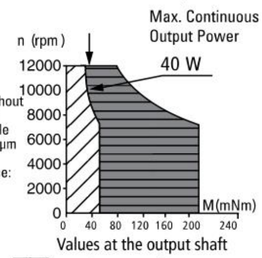
Max. Recommended Speed



Values at the output shaft

Continuous working range
Temporary working range