MTE 322 Winter 2021

University of Waterloo

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Project 1 (b)

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Item 1

Find: P [hp], corresponding motor.

From Proj 1a, $P_{i_{\text{worm gear}}} = 106.108\ W$

$$P_{motor} = 106.108\ W \times \frac{1\ hp}{746\ W} = 0.1423\ hp$$

Motor choice:

Nidec T13C2J Model: C055KJC4952015B

HP = 1/3 RPM: 1800 Voltage: 115 V

Frame: 56 Phase: 1 Enclosure: TEFC

Material: Rolled steel Mounting: Rigid

Parts:

Worm: 57545K621

Gear: 57545K698

Nidec T13C2J

Nidec · General Purpose Single Phase Capacitor Start TEFC Rigid Base

1/3 HP 1725 56 TEFC 115V|208-230V GENERAL PURPOSE

Catalog Number: T13C2J
Model Number: C055KJC4952015B

HP	1/3
RPM	1800
VOLTAGE	115V, 208-230V
FRAME	56
PHASE	1
ENCLOSURE	TEFC
MATERIAL	Rolled Steel
MOUNTING	Rigid

Item 2

These were found using "measure" tool in SW

worm gear: Pitch diameter: 50mm ✓
Teeth : 20 ✓
OD : 57.44 ≈ 57.5 ✓ [mm]
Face width: 20.25mm ≈ 20[mm] ✓
ϕ : 20°

Worm: Length: 45.92mm ≈ 46mm ✓
(Found by drawing a circle that lines up, then measure its diameter → APPROXIMATION)
OD: 34.62mm ≈ 35mm ✓
pitch diameter: 30.04mm ≈ 30mm ✓

Therefore, the dimensions specified in the catalogue from McMaster-Carr are correct in the provided Solidworks models.

Item 3

1. Bearing types:

We will use angular contact ball bearings. The bearings must be able to handle high speeds, which gives:

- Deep groove ball bearing
- Angular contact ball bearings
- Cylindrical ball bearings

Since cylindrical ball bearings can't handle axial loads, it was eliminated. Angular contact b.b. can handle axial and radial loads better than deep groove b.b.. Therefore angular contact ball bearings were chosen.

Bearing arrangement:

For CD: D will be floating since it is not driving the chain. Since there is an applied force closer to C, it makes sense to have this end fixed.

For AB: The fixed vs floating end depends on what side the motor is. The motor will be placed at the B side for spacing purposes. Therefore, A will be floating and B will be fixed.

2. Minimum size calculation

From specifications, $N = 1000$ M revolutions, 10% failure rate. ($L_{10} = 1000$)

For ball bearings:

$C \geq P\sqrt[3]{L_{10}}$

C_{or} static
C_r dynamic

From Project 1:

$F_{Aa} = F_{Ba} = 7.2534$ N
$F_{Ar} = F_{Br} = 34.542$ N

But all axial forces are supported by bearing B. So this gives:

$F_{Aa} = 0$, $F_{Ar} = 34.542$ N

$F_{Ba} = 14.5068\ N$, $F_{Br} = 34.542\ N$

Angular contact ball bearings don't have axial load factors, so assume we don't take induced load into account.

Bearing A: Dynamic:

$\frac{F_A}{F_r} = 0 < e$

$P = F_r = 34.542\ N$

$C_r \geq 34.542(\sqrt[3]{1000})$

$C_r \geq 345.42$

All bearings fit this criteria.

Static:

Any contact angle:

$P_0 = 0.5 F_r$

$= 0.5(34.542)$

$= 17.271$

$C \geq 17.271(10)$

$C \geq 172.71$

Again, all bearings fit this criteria.

Smallest: 7900 AS $\to \phi = 25°$ } $d=10, D=22$ [mm]

7900 C $\to \phi = 15°$ }

Bearing B: Dynamic: $F_a = 14.5068$

$\frac{F_A}{F_r} = 0.420$

We can't use the same approach as above, so we will simply iterate on the charts:

7900AS $\frac{F_a}{C_{or}} = 0.01 \to e \approx 0.38 < \frac{F_a}{F_r}$

$P = (0.44)(34.542) + (1.47)(14.5068)$

$= 36.523$

$C_r \geq 36.523(10)$

$C_r \geq 365.23$ ✓

Static:

$\phi = 25°$ $P_0 = (0.5)(34.542) + (0.38)(14.5068)$

$P_0 = 22.78$

$C \geq 22.78(10)$

$C \geq 227.8$ ✓

$\phi = 15°$ $P_0 = (0.5)(34.542) + (0.46)(14.5068)$

$= 23.94$

$C \geq 239.4$

∴ Bearings A and B can both use the 7900AS or 7900C, $d=10, D=22, B=6, r=0.3, r_1=0.15$ [mm]

All bearings fit this criteria. Can use 7900AS or 7900C as above.

$f_{s_A} = \frac{C_0}{P_0} = \frac{2900}{17.271} = 167.91$

$f_{s_B} = \frac{C_0}{P_0} = \frac{2900}{22.78} = 127.3$

From project 1:

$F_{Ca} = 2 \times 16.886\ N = 33.772\ N$

$F_{Da} = 0\ N$

$F_{Cr} = 20.416\ N$

$F_{Dr} = 17.156\ N$

Bearing D: Dynamic:

$\frac{F_a}{F_r} = 0 < e$

$P = F_r = 17.156\ N$

$C_r \geq 171.56$

All bearings fit this criteria.

Static:

$P_0 = (0.5)(17.156)$

$P_0 = 8.578\ N$

$C_0 \geq 85.78$

Bearing C: Dynamic:

Iterate again as above.

$\frac{F_a}{F_r} = \frac{33.772}{20.416} = 1.65 > e$

7900AS: $\frac{F_a}{C_{or}} = 0.023 \to e \approx 0.38$

$P = (0.44)(20.416) + (1.47)(33.772)$

$= 58.628$

$C_r \geq 586.28$ ✓

Static

$\phi = 25°$ $P_0 = (0.5)(20.416) + (0.38)(33.772)$

$P_0 = 23.04$

$C_{or} \geq 230.4$ ✓

$\phi = 15°$ $P_0 = (0.5)(20.416) + (0.46)(33.772)$

$= 25.743$

$C_{or} \geq 257.43$ ✓

$f_{s_C} = \frac{2900}{25.743} = 112.65$

$f_{s_D} = \frac{2900}{8.578} = 338.07$

Item 4

For shaft CD:

At the gear: interference fit, since the shaft must move with the gear. (key)
The bearing at C will be interference fit due to it being a load-bearing area, and rotating.
The bearing at D will be a clearance fit. This will make it easier to assemble, and the shaft is not required to rotate with the inner ring.
At sproclet: interference fit (key)

C: 7900AS → $\varnothing = 10$ mm

Choose H7: $\left.\begin{matrix} +0.0 \\ +0.015 \end{matrix}\right\}$ 10 - 10.015 mm ✓ int.

r6: $\left.\begin{matrix} +0.019 \\ +0.028 \end{matrix}\right\}$ 10.019 - 10.028 mm

D: 7900AS → $\varnothing = 10$ mm

Choose H7: $\left.\begin{matrix} +0.0 \\ +0.015 \end{matrix}\right\}$ 10 - 10.015 mm ✓ clear.

choose d9: $\left.\begin{matrix} -0.04 \\ +0.036 \end{matrix}\right\}$ 9.96 - 9.996 mm

Gear → $\phi = 12$ mm
choose U4 : $\left.\begin{matrix} -0.033 \\ +0.004 \end{matrix}\right\}$ 11.967mm − 11.971 m ✓ int.

Use key 98870A704 key → 3mm × 3mm
Ht Tol: −0.025 mm +0.0 mm
11.975 mm − 12.00 mm

Sprocket → $\phi = 9$ mm
Use 98870A704 key → 3mm×3mm
Ht. Tol: −0.025 to 0.0 mm

8.975 mm − 9 mm
choose U1 : $\left.\begin{matrix} -0.028 \\ +0.001 \end{matrix}\right\}$ 8.972 − 8.973 mm ✓
int.

For AB:
A → floating → clearance fit for easier assembly
B → fixed → interferance
Since the same bearings are being used, we can use the same tolerances as above.

B: 7900AS → $\phi = 10$ mm
Choose H7 : $\left.\begin{matrix} +0.0 \\ +0.015 \end{matrix}\right\}$ 10 − 10.015 mm ✓ int.
r6 : $\left.\begin{matrix} +0.019 \\ +0.028 \end{matrix}\right\}$ 10.019 − 10.028 mm

A: 7900AS -> $\emptyset = 10$ mm

Choose H7: $+0.0$, $+0.015$ } 10-10.015 mm

choose d9: -0.04, $+0.036$ } 9.96 - 9.996 mm

✓ clear.

There will be snap rings about each of the bearings, as well as the gear and sprocket.

Use 98541A118 retaining rings for bearings.

T = 1 mm   steel

$$R_S = 1 \times \frac{980 \times \pi \times 1 \times 10}{12 \text{ (worst case)}}$$

$$= 2565.634 \text{ N}$$

Assume $\sigma_y = 550$ [N/mm^2]

$$G \doteq 1 \times \frac{10 \times \pi \times 0.7 \times 550}{12 \times 4 \text{ (worst case)}}$$

$$G = 251.98 \text{ N}$$

from proj 1 a)

$F_{Ax} = F_{Bx} = 16.886 < G$ ✓

$F_{Cx} = 33.772 < 143.984$ ✓

$F_{Dx} = 0 < G$ ✓

<u>Key shear strength analysis</u>:

$\sigma_1 - \sigma_3 \geq S_y$

From textbook → 1045 carbon steel

$S_y = 530$ MPa

Gear: $\sigma_1 - \sigma_3 \geq S_y$

$2 \frac{W_t}{A} \geq S_y$

From proj 1: $W_t = 85.836$ lbf $= 381.830894$ N

$A = 3mm \times 3mm$

$$2\left(\frac{381.8309}{9 \times 10^{-6}}\right)(10^{6}) = 84.85 MPa$$

$84.85 MPa \geq S_y$ ✓

Sprocket:

$$2\left(\frac{200N}{9 \times 10^{-6}}\right)(10^{6}) = 44.44 MPa$$

44.44 MPa $\geq S_y$ ✓

Use 98541A117 for sprocket

$$R_s = \frac{980 \times \pi \times 9}{12} = 2309.07$$

$$G = \frac{9 \times \pi \times 0.6 \times 550}{12 \times 4} = 194.38$$

No force thrust force in this direction. The groove is only holding up the weight of the sprocket.

Use 98541A119 for gear

$$R_s = \frac{980 \times \pi \times 12}{12} = 3078.76 \text{ N}$$

$$G = \frac{12 \times \pi \times 1 \times 550}{12 \times 4} = 431.97 \text{ N}$$

From project 1: $W_{xG} = 33.772$ N

$W_{xG} < G$ ✓