A steel worm running at 240 rpm receives 1.5 kW from its shaft. The speed reduction is 10:1. Design the drive so as to have an efficiency of 80%. Also determine the cooling area required, if the temperature rise is restricted to 45°C. Take overall heat transfer co-efficient as 10 W/m²°C

Given Data:

$N_1 = 240$ r.p.m, $P = 1.5$ kW, $i = 10$, $\eta_{desired} = 80\%$,

$t_o - t_a = 45°C$, $k_t = 10$ W/m² °C.

To find:

1) Design the worm gear drive
2) The cooling area required (A).

Solution:

1) Selection of material:

Worm - steel
Wheel - Bronze (sand cast)

2) Calculation of initial design wheel torque $[M_t]$:

$$[M_t] = M_t \times K \times K_d$$

$$M_t = \frac{60 \times 1.5 \times 10^3}{2\pi \times 24}$$

$$M_t = 596.83 \text{ N-m}.$$

3) Selection of z_1 and z_2:

For $\eta = 80\%$, $z_1 = 3$ (or) 4

$z_2 = i \times z_1 = 10 \times 3 = 30$.

Selection of $[\sigma_b]$ and $[\sigma_c]$:-

* For bronze wheel $\sigma_u < 390\ N/mm^2$

$[\sigma_b] = 50 N/mm^2$.

$[\sigma_c] = 159\ N/mm^2$. , $V_s = 3\ m/s$.

Calculation of centre distance (a) :-

$$a = [(z_2/q)+1] \sqrt[3]{\left[\frac{540}{(z_2/q)\ [\sigma_c]}\right]^2 \frac{[M_t]}{10}}$$

$\Rightarrow 188.6\ mm$.

Calculation of axial module :-

$$m_x = \frac{2a}{(q+z_2)} = \frac{2 \times 168.6}{(11+30)} = 8.22\ mm$$

Revision of centre distance :

$$a = 0.5\ m_x (q + z_2) = 0.5 \times 10\ (11 + 30)$$

$\Rightarrow 205 mm$.

Calculation of d, v, γ, V_s :-

Pitch diameters $d_1 = q \times m_x = 110 mm$.

$d_2 = z_2 \times m_x = 300\ mm$.

Pitch line velocity $v_1 = \frac{\pi d_1 N_1}{60} = 1.382\ m/s$.

$v_2 = \frac{\pi d_2 N_2}{60} = 0.377\ m/s$.

Lead Angle $\gamma = \tan^{-1}\left(\frac{z_1}{q}\right) =$

$\tan^{-1}\left(3/_{11}\right) = 15.25$

Sliding Velocity $V_s = \frac{v_1}{\cos \gamma} = \frac{1.382}{\cos 15.25°} = 1.432\ m/s$.

9) Recalculation of design contact stress $[\sigma_c]$:-

For $V_s = 1.432$ m/s, $[\sigma_c] \approx 172$ N/mm². from table 8.10

10) Revision of $[M_t]$:-

If $V_2 < 3$ m/s, $k_d = 1$

$$[M_t] = M_t \times k \cdot k_d = 596.83 \times 1 \times 1$$

$$\Rightarrow 596.83 \text{ N-m}$$

11) Check for bending :-

We know that the induced bending stress,

$$\sigma_b = \frac{1.9\,[M_t]}{m_x^3 \times q \times z_2 \times y_v}$$

y_v = Form factor based on virtual roof teeth. from table 5.13.,

$$z_v = \frac{z}{\cos^3\gamma} = \frac{30}{\cos^3 15.25} = 34$$

$$y_v \approx 0.452 \quad z_v = 34$$

$$\sigma_b = \frac{1.9 \times 596.83 \times 10^3}{(10)^3 \times 11 \times 30 \times 0.452} \Rightarrow 7.6 \text{ N/mm}^2.$$

We find $\sigma_b < [\sigma_b]$ thus the design is satisfactory against bending.

12) Check for wear :-

$$\sigma_c = \frac{540}{(z_2/q)} \sqrt{\left[\frac{(z_2/q)+1}{a}\right]^3 \times \frac{[M_t]}{10}}$$

$$\Rightarrow 118.59 \text{ N/mm}^2.$$

$\sigma_c < [\sigma_c]$ thus the design is safe and satisfactory.