DESIGN PROJECT # 1

Due to Friday, November 26, 2021

Use the following numbers in your calculations

If only one person is doing the project

Your school ID →

a ←

b ←

If two people are doing the project together

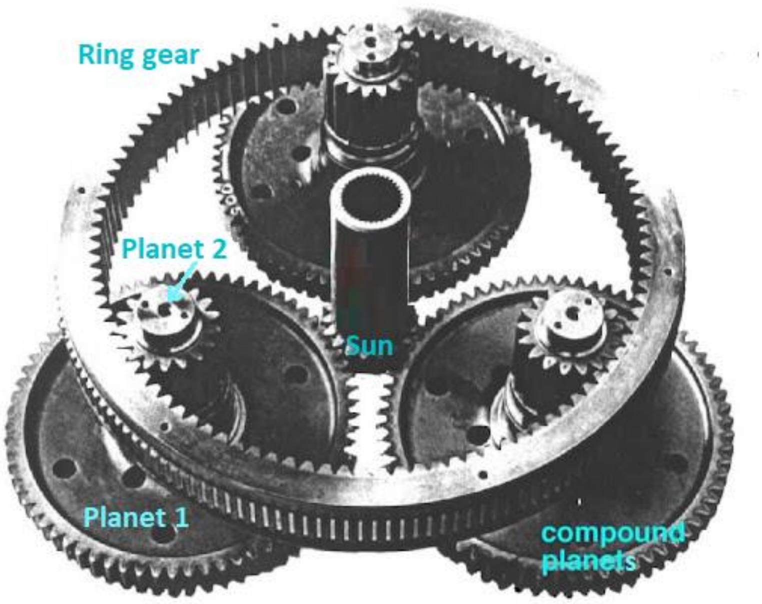
First person's school ID →

a ←

Second person's school ID →

b ←

In the planetary gear train shown in the figure, the input power is transferred to two gears; the external central gear (the sun gear) and the internal gear (the ring gear), output power is taken from the arm (not shown). These gears rotate with angular speeds ω_s and ω_r. The positive sense of rotation is considered as the clockwise rotation. The compound planets are mounted on the same shaft rotating with the same angular speed. One set of planet gears (planet 1) are meshed with the sun gear; another set of planet gears (planet 2) are meshed with the ring gear ($\omega_{p1} = \omega_{p2} = \omega_p$). The arm (or carrier) (not shown) is connected the shafts of the planet gears and it moves with the same speed as their centers. Power is taken from the arm. **(*a*)** Derive a relation between the angular speed of the arm, ω_a and the input speeds (ω_s and ω_r) in terms of the number of teeth in the gears. Show your steps clearly. **(*b*)** Consider the case in which the ring is fixed. Find the tangential forces between the sun and planet 1, between the ring and planet 2, and also find the force applied by planet 2 to the arm in terms of the input power, $\dot{W}$, pitch diameters, and the speeds. Show your steps clearly.



(*c*) Consider the case in which the ring is fixed. Develop a computer program to design for proper gearing such that the transmitted power is **maximum**. The design requires a bending safety factor at least 1.5 and a surface safety factor of at least 1.2 with 99 % reliability. Safe use of 1×10^8 revolutions of the arm is required. Power is taken from an electric motor and delivered to a punch press through this transmission. The sun is rotated at $(3000 + 100a)$ pm. The arm is required to rotate at a speed between $(90 + 5b)$ and $(180 + 10b)$ rpm. The teeth have standard involute profile with 20° pressure angle. All the gears have the same module and face width. Power loss is negligibly small. Mountings correspond to good industrial practice but not high precision. Teeth are finished by average quality hobbing. HB of the steel material is between 200 and 400. There should be no interference between any meshed gear pairs. This transmission must fit within a housing having a maximum inner diameter of $(450 + 10a)$ mm. There should be 5 mm clearance between the gears and the housing. The maximum pitch line velocity should be less than 25 m/s. Use SI units. **Print out your program and output file**. The output file should include the following **in**

the given order: Power transmitted, material (HB), input speed (n_s (rpm)), output speed (n_a (rpm)), module, pitch diameters of the gears (d_s, d_{p1}, d_{p2}, d_r), number of teeth of the gears (N_s, N_{p1}, N_{p2}, N_r), inner diameter of the housing, speeds of the planets (n_p (rpm)), pitch line velocity of the sun (v_{sp}), tangential force between the sun and planet 1 (F_{sp1}), tangential force between the ring and planet 2 (F_{pr}), the force applied by planet 2 on the arm (F_{arm}), face width (b), contact ratio (CR) between the sun and planet 1 and between the ring and planet 2, interference check for these pairs of gears ($r_{ap.max}$ - r_{ap} and ΔN - ΔN_{min} comparisons), specify the most critical gear. Give the following quantities for the most critical gear (having the lowest safety factor): J, K_v, K_m, K_o, bending stress (σ_b), S'_n, C_L, C_G, C_S, k_r, k_{ms}, endurance limit (S_n), safety factor against fatigue failure due to bending stresses, C_p, I, surface fatigue stress (σ_H), S_{fe}, number of contacts that its teeth make contact during 1×10^8 revolutions of the arm, C_{Li}, C_R, surface fatigue strength (S_H), safety factor against surface failure. The computer program should read the inputs from an input file or within the program and find the values of design variables without user intervention through iterations. **(*d*)** Write a report containing the analysis of the optimum design by hand calculations.

Hint: 1. The life requirement is given as the number of rotations of the driven shaft. However, the number of times a gear tooth is subjected to contact forces may be different. 2. In evaluating the K_v factor, the pitch line velocity, v, can be taken as the average of the maximum pitch line velocities of the engaged gears. The same value for v should be used for both engaged gears. Besides, the limit on the maximum allowable pitch line velocity can be checked using the average value.

Note: Two people may form a project group and work on the project together. However, project groups may not get any help from each other. Do not show your code to another group. Any similarity in the algorithm and computer code will be presumed as cheating.