Mechanics & Machines Course

Nabila Adawy

B19-RO-01

Bird Wing Simulation

Kinematics

Report

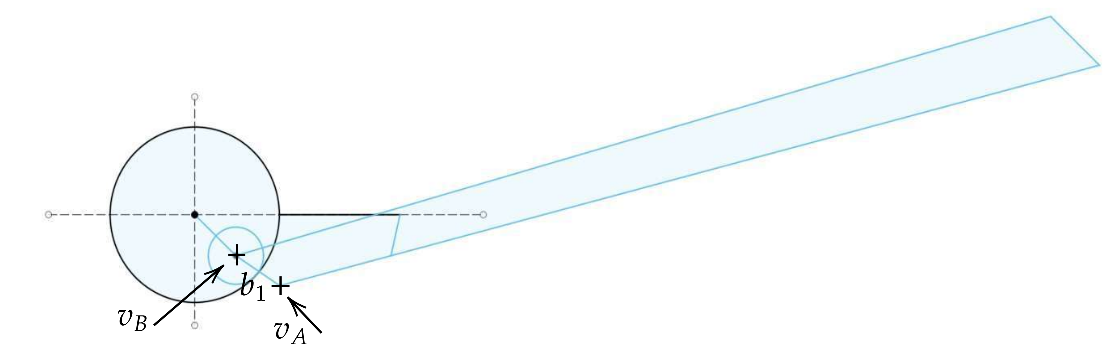
Presented To: **Oleg Bulichev**

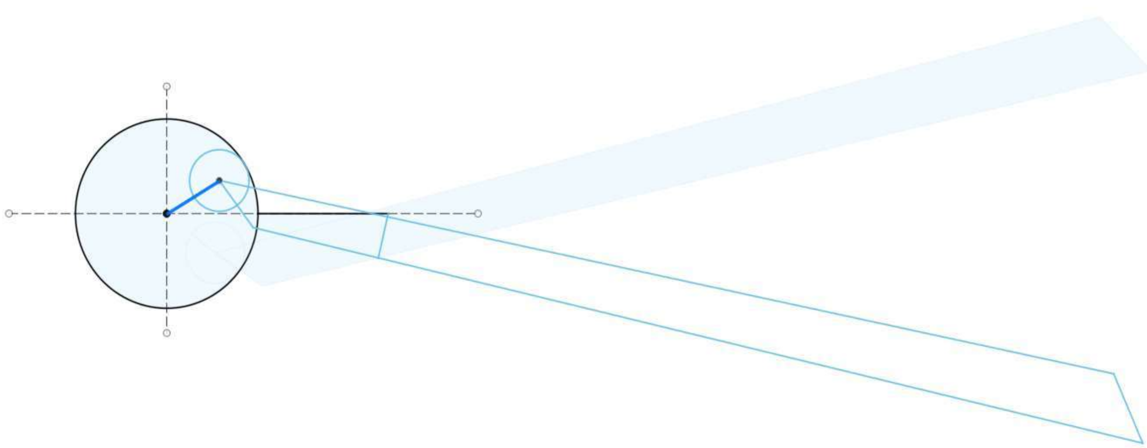
Introduction:

Our goal is to find the positions (and velocities) of a mechanism that simulates the motion of a bird wing. Due to the complex motion, we can divide the mechanism into 3 separate mechanisms to simplify the calculations.

Mechanism Declaration:

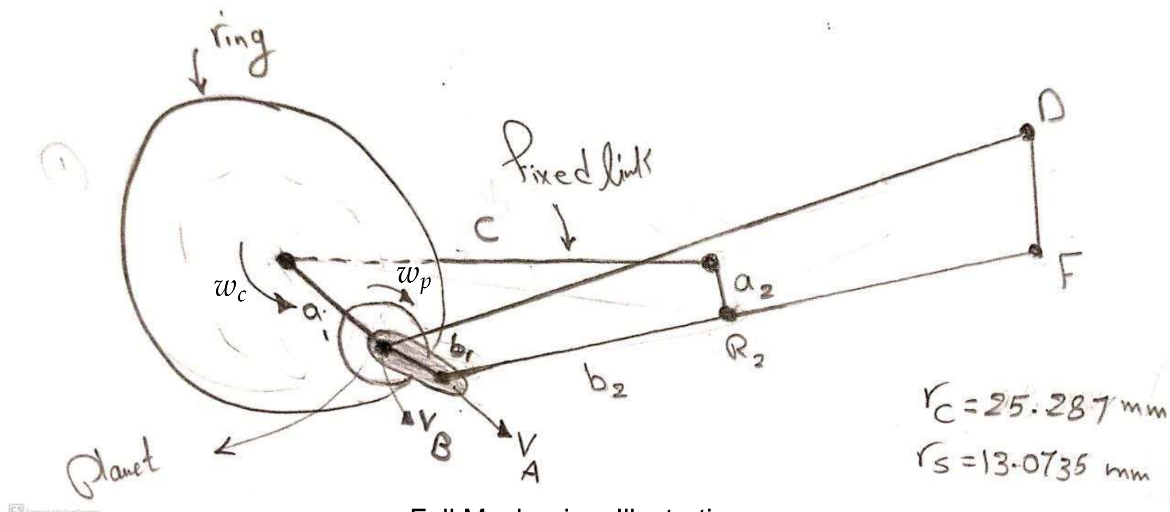
First of all, here is an illustration of how the mechanism of one wing works. I will proceed explaining everything on one wing. And the other wing will have the same equations with inverted signs so nothing new.





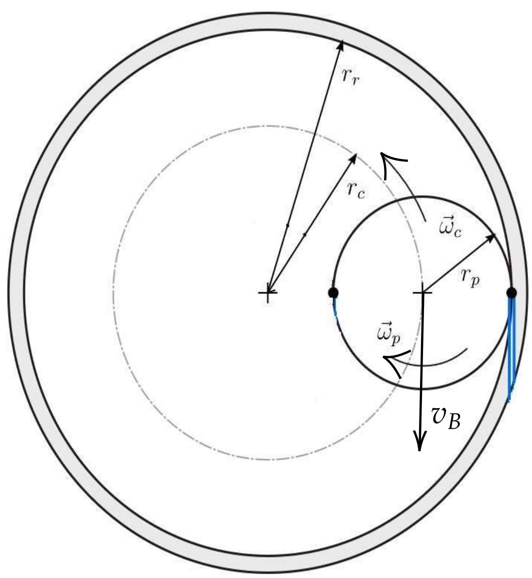
Basically, I can split the mechanism into 3 mechanisms to make it simpler in kinematic analysis.

- First Mechanism is planetary gear.
- Second Mechanism is 5-bar linkage.
- Third Mechanism is 4-bar linkage.



Full Mechanism Illustration

Planetary Gear Mechanism:



we have a stationary ring gear, with number of teeth $z_r = 28$ and a rotating planet gear with number of teeth $z_p = 12$.
from the equations of planetary gear explained [here](), we can obtain 2 equations of the ratios between the angular velocity of planetary gear w_p and the angular velocity of the carrier w_c as follows:

$$\frac{w_c}{w_p} = \frac{r_p}{r_r} = \frac{z_p}{z_r} = \frac{12}{28} = \frac{7}{3}$$

$$\boxed{w_p = \frac{r_r}{r_p}.w_r} \quad rad/s \qquad (1)$$

$$where\ r_r\ \&\ r_p\ are\ radiuses\ of\ ring\ and\ planetary\ gears.$$

$$also$$

$$\boxed{w_p = \frac{r_s}{r_r}\,w_c} \quad rad/s \qquad (2)$$

$$since: \; r_s = r_c - r_p$$

$$also \; we \; can \; obtain \; the \; velocity \; at \; point \; B \; \& \; A (in \; the \; overall \; mechanism):$$

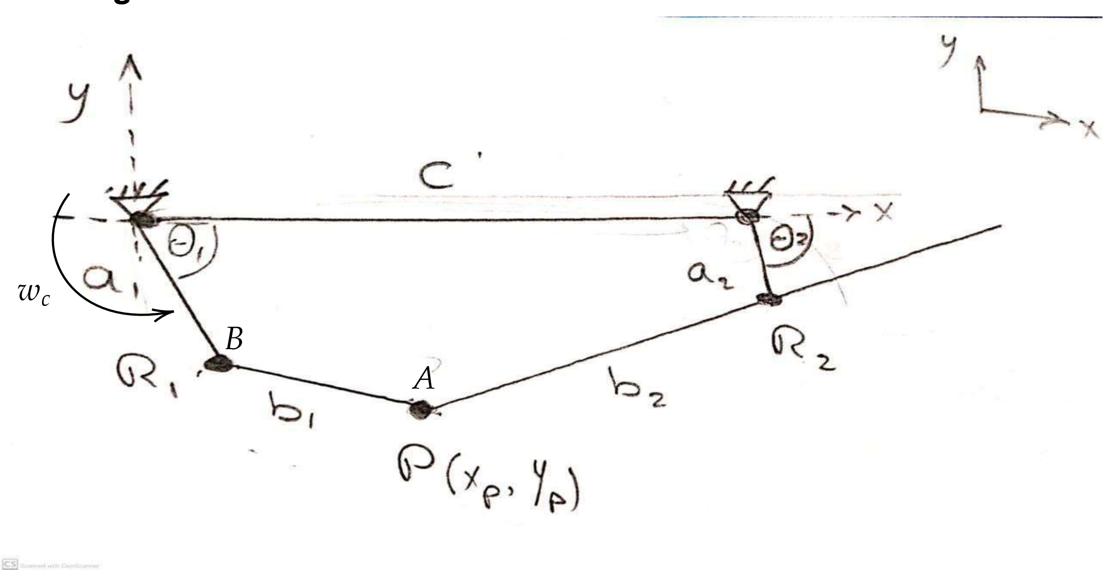
$$\boxed{v_B = w_c \, r_c} \; m/s$$

$$\boxed{v_A = (w_c - w_p) \, b_1} \; m/s$$

Primary parameters:

$$r_r = 37.5 \; mm$$
$$r_p = 12.2135 \; mm$$
$$r_c = 25.287 \; mm$$
$$r_s = 13.0735 \; mm$$
$$b_1 = 23.261 \; mm$$

5-Bar Linkage Mechanism:



First, we can find position of point R_1:

$$\boxed{\begin{aligned} x_{R_1} &= a_1 \cos(\theta_1) \\ y_{R_1} &= -a_1 \sin(\theta_1) \end{aligned}} \; mm$$

Second, we can find position of point R_2:

$$\boxed{\begin{aligned} x_{R_2} &= a_2 \cos(\theta_2) + c \\ y_{R_2} &= -a_2 \sin(\theta_2) \end{aligned}} \; mm$$

Then, we can find position of point P as an intersection between two circles with radius PR_1 & PR_2.

$$\boxed{\begin{aligned} (x_p - x_{R_1})^2 + (y_p - y_{R_1})^2 &= b_1^2 \\ (x_p - x_{R_2})^2 + (y_p - y_{R_2})^2 &= b_2^2 \end{aligned}} \; mm$$

$$2 \; equations \; \& \; 2 \; unkown \; we \; can \; obtain \; x_b \; \& \; y_b$$

After having all the positions of all points, we can obtain the velocities as the derivatives of the positions as follows:

$$v_{R1} = \sqrt{\dot{x}_{R_1} + \dot{y}_{R_1}} = v_B \quad m/s$$

$$v_{R2} = \sqrt{\dot{x}_{R_2} + \dot{y}_{R_2}} \; m/s$$

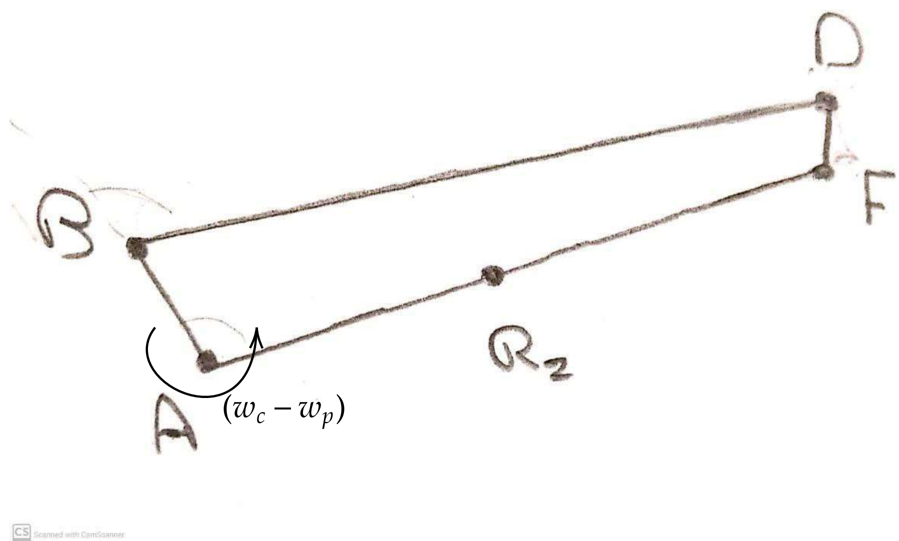
$$v_p = \sqrt{\dot{x}_p + \dot{y}_p} = v_A \; m/s$$

Note: if we'll need the accelerations, we can find them at each point by the derivatives of the velocities.

Primary parameters:

$$a_1 = 25.287 \ mm$$
$$a_2 = 18 \ mm$$
$$b_2 = 47.597 \ mm$$
$$c = 90.989 \ mm$$

4-Bar Linkage Mechanism:



As we already know the positions & velocities of point A & B, so we only need to find the positions of point F & D. Which can be obtained as intersections between two circles as follows:

$$Postion\ of\ D:$$
$$\boxed{\begin{aligned}(x_D - x_B)^2 + (y_D - y_B)^2 &= BD \\ (x_D - x_F)^2 + (y_D - y_F)^2 &= DF\end{aligned}} \ mm$$

$$Position\ of\ F:$$
$$\boxed{\begin{aligned}(x_F - x_A)^2 + (y_F - y_A)^2 &= AF \\ (x_F - x_D)^2 + (y_F - y_D)^2 &= DF\end{aligned}} \ mm$$

$$4\ equations,\ 4\ unkowns,\ then\ we\ can\ obtain:$$
$$x_D, y_D\ \&\ x_F,\ y_F$$

Then we can obtain the velocities as the derivatives of the positions:

$$v_D = \sqrt{\dot{x}_D + \dot{y}_D} \ \ m/s$$
$$v_F = \sqrt{\dot{x}_F + \dot{y}_F} \ \ m/s$$

Primary parameters:

$$AB = b_1$$
$$FD = 30 \ mm$$
$$BD = 375.362 \ mm$$
$$AF = 374.362 \ mm$$

Results:

I tested my equations on GeoGebra, and you check it from this **Link (https://www.geogebra.org/calculator/ckuxrbtj)**