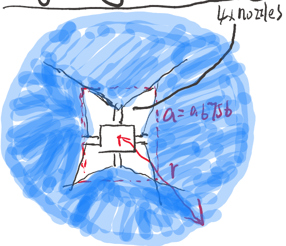
Trajectory Calculation



We assume the fish food will be ejected from the nozzle at various angles, with the highest probability being that it will be ejected in different directions at a horizontal speed. (the exit is horizontal). Therefore we assume the area could covered is the blue circle region without the white region around by nozzles which will be considered as a square with a = 0.6756 m.

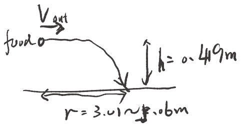
$$A_{need} = (28 - 80)\,m^2$$

$$A_{real} = \pi r^2 - a^2 = \pi r^2 - (0.6756)^2$$

$$r = \sqrt{\frac{A_{real} + (0.6756)^2}{\pi}}$$

$$= \sqrt{\frac{(28 \sim 80) + (0.6756)^2}{\pi}}$$

$$= 3.01 \sim 5.06\ m$$



$$h = 0.49 = \frac{1}{2} g t^2$$

$$t = \sqrt{\frac{2 \times 0.49}{g}} = 0.3025$$

Ignore wind-effect

$$V_{out} = 9.967 \sim 16.755\ m/s$$

Consider the friction from winding, Anti-wind direction:

$$F_d = \frac{1}{2} C_d \rho A v^2$$

$C_d = 0.47$ for spherical particles

$d = 3\,mm$

V_{wind}: $80\,km/h = 22.22\,m/s$

$$A_{food} = \pi \left(\frac{d}{2}\right)^2 = \pi \times (0.0015)^2 = 7.07 \times 10^{-6}\,m^2$$

$$\rho_{food} = 600\ kg/m^3$$

$$m = \rho_{food} \frac{4}{3}\pi \left(\frac{d}{2}\right)^3 = 600 \times \frac{4}{3}\pi (0.0015)^3 = 8.48 \times 10^{-6}\,kg$$

Horizontal direction

$$a = \frac{dv_x}{dt} = \frac{F_D}{m} = -\frac{C_d \rho_{air} A}{2m} (V_x + V_{wind})^2$$

$$\frac{dV_x}{dt} = -\frac{0.47 \times 1.225 \cdot 7.07 \times 10^{-6}}{2 \times 8.48 \times 10^{-6}} (V_x + 22.22)^2$$

$$\frac{dV_x}{dt} = -0.24\, V^2$$

$$\int_{V_0}^{V} \frac{1}{V(t)^2} dv = -k \int_0^t dt$$

$$\Rightarrow \frac{1}{V(t)} - \frac{1}{V_0} = kt$$

$$V(t) = \frac{V_0}{1 + k t V_0}$$

After integral $S = \int_0^t V(t)\,dt = \frac{1}{k} \ln|1 + k v_0 t|$

$$= 3.01 \sim 5.06$$

$$\ln|1 + k v_0 t| = (3.01 \sim 5.06) \times 0.24$$

$$V_0 = 14.616\ m/s \sim 32.675\ m/s$$

Accessible

Storage Calculation

8 modules to storage

the geometry of 8 modules are triangular pyramid $V_{real} = \frac{1}{3}h(A_1 + A_2 + \sqrt{A_1A_2})$

Basic parameters for my design: $h = 0.189m$ upper face: $a_1 = 0.3446m$ $a_2 = 0.1978m$

Equilateral right triangle

$8 \times V_{need} = \frac{m}{\rho} = \frac{2kg}{600\,kg/m^3} = 0.003333\ m^3$ per module

$A_1 = \frac{\sqrt{3}}{4}a_1^2 = \frac{\sqrt{3}}{4} \times (0.3446)^2 = 0.05142m^2$

$A_2 = \frac{\sqrt{3}}{4}a_2^2 = \frac{\sqrt{3}}{4} \times (0.1978)^2 = 0.01694m^2$

$$V_{real} = \frac{1}{3}h(A_1 + A_2 + \sqrt{A_1A_2})$$
$$= \frac{1}{3} \times 0.189(0.05142 + 0.01694 + \sqrt{0.05142 \cdot 0.01694}$$
$$= 0.006166m^3 \geq 0.003333 = V_{need}$$

almost 2 times If arrive or on business trip. We could add up to maximum

Screw feed calculation (Objective: screw 2kg per time)

Basic parameters

$r = 0.1568$ $D = 0.3136$ pitch: $P = 0.01$, $\rho_{food} = 500\,kg/m^3$, assume $\eta = 60\%$

$$C_{per\ cycle} = \pi \cdot \left(\frac{D}{2}\right)^2 \cdot P \cdot \eta \cdot \rho_{food} = \pi \times \left(\frac{0.3136}{2}\right)^2 \times 0.01 \times 0.6 \times 500$$
$$= 0.23172\ kg/cycle$$

cycle number $n = \frac{2kg}{0.23172kg/clcle} = 8.631$ cycle

For the micromotor we choose 57HS22 step motor + Reducer with ratio of 10:1

Basic parameters: $T_{rated} = 1.2$
$N = 30RPM$

After reduce N: $T_{rated}' = 1.2 \times 10 = 12$

$$N' = \frac{30RPM}{10} = 3RPM$$

Time:

$$t = \frac{8.62\,cycle}{3\,RPM} = \boxed{2.87\ min}$$ to feed 2kg

Torque verification

$G_{food} = 2kg \times 9.81 = 19.62N$

$F_{friction} = \mu G = 0.4 \times 19.62 = 7.85N$

$f_{Blades\ and\ tubes\ wall}$ assume $= 5N$ $F_{tot} = 32.47N$

$T_{need} = F_{tot} \cdot r = 32.47 \times 0.1568 = 5.1N \cdot m$

$T_{rated} = 12N \cdot m > T_{need} = 5.1N \cdot m$

It mean the step motor has sufficient torque to drive this screw conveyer

Air pump spray Calculation

The box connected to nozzles could hold

$$V = h \cdot \frac{\pi D^2}{4} = 0.162 \times \frac{\pi \times (0.162)^2}{4} = 0.00334\ m^3$$

$$m = V \cdot \rho_{food} = 0.00334 \times 600\,kg/m^3 = 2.0035\,kg > 2\,kg \text{ per day Fish food}$$

So food could be spray by air pump in one time

Dynamic Pressure for air is $\Delta P = \frac{1}{2} \rho_{air} V_{air}^2$ $\quad \rho_{air} = 1.2\,kg/m^3$

V_{air} is ralated to. V_{food} ($14.616\,m/s \sim 32.675\,m/s$)

In practice Due to friction, particle inertia and so on. it is necessary to introduce energy transfer efficiency.

$$\eta_{transfer} \approx 20\%$$

$$V_{food} = V_{air} \times \sqrt{\eta_{transfer}}$$

$$V_{air} = \frac{V_{food}}{\sqrt{\eta_{transfer}}} = \frac{14.616}{\sqrt{0.2}} = 32.68\ m/s$$

Dynamic Pressure: $\Delta P = \frac{1}{2} \times 1.2 \times (32.68)^2$

$$= 640.88\ Pa$$

Total Pressure for system need to overcome.

Dynamic $P = 640.88\ Pa$

Friction of pipeline $\Delta P_f = f \cdot \frac{L}{d} \cdot \frac{1}{2} \rho_{air} V_{air}^2$

$$= 0.02 \times \frac{0.185}{0.028} \times 640.88$$

$$= 84.69\ Pa$$

Local friction

(Nozzle contraction $K = 0.5$) $\Delta P_{local} = K \cdot \Delta P_f = 0.5 \times 640.88$

$$= 320.44\ Pa$$

$$\Delta P_{tot} = 640.88 + 84.69 + 320.44 = 1046\,Pa = 0.01046\ bar$$

$$P_{input} = P_{atm} + \Delta P_{tot} = 1\ bar + 0.01046 = 1.01046\ bar$$

Therefore we choose a small portable air pump which has a pressure range of 0.7~10 bar completely meet the dynamic pressure requirement.

Air pump power Consumption Calculation

Mass rate: $\dot{m}_{food} = \frac{2kg}{172.2} = 0.0116 kg/s$

Asumme mix ratio between air and fish food is 1:10

$\dot{m}_{air} = 0.0116 \times 10 = 0.116 \ kg/s$

Volume rate: $Q_{air} = \frac{\dot{m}_{air}}{\rho_{air}} = \frac{0.116}{1.2} = 0.0967 \ m^3/s$

$P_{theory} = \Delta P_{total} \cdot Q_{air} = 1046 \times 0.0967$

$= 101.15 \ W$

$\eta_{pump} = 50\% \quad \eta_{motor} = 80\%$

$P_{actual} = \frac{P_{theory}}{\eta_{pump} \cdot \eta_{motor}} = \frac{101.15}{50\% \times 80\%} = 252.87 \ W$

$E_{pump} = 252.87 \times \frac{172.2}{3600} = 12.096 \ Wh$

Water pump calculation

Surface Area need to clean (Screw conveyer) $= 1.118 \times 2\pi \times 0.224$

$= 1.57\ m^2$

According to experience $V_{water} = 10\ L/m^2 \times A$

$= 10 \times 1.57$

$= 15.7\ L$ water

$\dot{Q}_{pump} = 2\ L/min$

$$t = \frac{V_{water}}{\dot{Q}_{pump}} = \frac{15.7L}{2L/min} = 7.85\ min$$

$\eta_{water\ pump} = 50\%$

$H = 1.772\ m$
(Lift)

$$P_{water\ pump} = \frac{Q \cdot \rho g \cdot H}{\eta} = \frac{2 \times 1000 \times 9.81 \times 1.772}{3600 \times 0.5}$$

$$= 19.3148\ W$$

Therefore we choose 12V, 2A small water pump to meet the power acquirement.

$$E_{water\ pump} = P_{water\ pump} \cdot t$$

$$= 19.3148 \times \frac{7.85}{60}$$

$$= 2.527\ Wh$$

Solar panel supply calculation (10W solar panel)

<1> **Power we need per day:** $E_{motor} = P \cdot t = V \cdot I \cdot t = 12V \times 2A \times \frac{172s}{3600}$

$= 1.15 Wh / day$

$E_{air\ pump} = 12.096\ Wh / day$ (See previous)

$E_{fan} = 2W \times 24 = 48 Wh/day$

$E_{strawberry\ PI} = 1.5W \times 24 = 36 Wh/day$

$E_{water\ pump} = 2.527 Wh/day$

$E_{small\ display} = 5W \times 24h = 120 Wh$

$E_{total} = E_{motor} + E_{airpump} + E_{fan} + E_{strawberry\ PI} + E_{waterpump}$

$= 1.15 + 12.096 + 48 + 36 + 2.527 + 120 Wh$

$= 219.773 Wh$

<2> **Solar panel supply per day:**

$b = 0.942$ $h = 0.85238$ $A = 0.942 \times 0.85238 = 0.803 m^2$

Theoretical parameters: $\eta = 15\%$ cummerial standard.

$t = 5h/day$ Sunshine time (Average)

$1000 W/m^2$ Solar irradiance (standard test)

$E_{supply} =$ A × efficiency × irradiance × sunshine time

$= 0.803 \times 0.15 \times 1000 W/m^2 \times 5$

$= 602.25 Wh / day \gg E_{total} = 219.773 Wh/day$

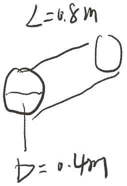
The solar panel supply is sufficient and the redundant energy could be store in Battery as backup power supply.

Floats and stability calculation (including anchors)

1. Calculate the Buoyancy and Draft $M_{system} = 51.5852$

$$F_B = \rho g V = Mg$$

$$V = \frac{m}{\rho} = \frac{51.5852}{1000} = 0.0516\ m^3$$



Because we have four floats

$$V_{sub} = \frac{V}{4} = 0.0128963\ m^3$$

$$V(h) = 2 \cdot A(h)$$

$$A(h) = r^2 \cdot \cos^{-1}\left(\frac{r-h}{r}\right) - (r-h)\sqrt{2rh-h^2}$$

$$V(h) = 0.8 \cdot \left[0.04\cos^{-1}\left(1-\frac{h}{0.2}\right) - (0.2-h)\sqrt{0.4h-h^2}\right]$$

We should find an appropriate Draft h to make $V(h) = V_{sub} = 0.0128963$

After solving this equation we found that

Draft $h = 0.074\ m$ $\quad V(h) = 0.01288 \approx V_{sub}$

2. Calculate the Metacentric Height GM

$$GM = KB + BM - KG$$

KB: Center of Buoyancy; BM: Metacentric Radius; KG: Center of Gravity $= 0.988$

$$KB = \frac{h_{sub}}{2} = \frac{0.074}{2} = 0.037\ m$$

$BM = \frac{I}{V}$, where I is moment of inertia of water surface. V is total displacement volume.

Float spacing $S = 0.762\ m$

$w(h) = 2\sqrt{2rh_{sub} - h_{sub}^2} \approx 0.316\ m$

$$BM = \frac{I}{V} = \frac{4 \cdot A \cdot \left(\frac{S}{2}\right)^2}{V} = \frac{4 \cdot L \cdot w(h) \cdot \left(\frac{S}{2}\right)^2}{V}$$

$$= \frac{4 \times 0.8 \times 0.316 \cdot 0.145}{0.05152} = 2.8\ m$$

$$GM = KB + BM - KG = 0.037 + 2.8 - 0.988 = 1.846\ m > 0$$

Therefore this shows that the system is stable at small tilt angles

3. 80km/h winding — stability analysis

Assume tilt angles is $\theta = 12^\circ$ according to pdf guidance

① Restoring moment

$$M_r = m \cdot g \cdot GM \cdot \sin\theta = 51.5852 \times 9.81 \times 1.846 \times \sin 12^\circ$$
$$= 194.25 \ N \cdot m$$

② Wind Load moment M_D $\quad$ 80km/h = 22.22 m/s

$$F_D = C_d \cdot A \cdot \tfrac{1}{2} \rho V^2 = 1 \times 0.5 \times \tfrac{1}{2} \cdot 1.2 \times 22.22^2$$
$$= 148.1 \ N$$
$$M_D = F_D \cdot h_w = 148.1 \times 0.7 \times \cos(12^\circ)$$
$$= 101.417 \ N \cdot m < M_r = 194.25 \ N \cdot m$$

The system can withstand wind Loads without capsizing at wind speeds of 80 km/h.