ME3100 - WINGSUIT MECHANISM

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WINGSUIT FLIGHT

OBJECTIVE

- To analyse the physics behind the gliding of **THE BATMAN**
- Batman's gliding mechanism is similar to that of a wingsuit.
- Therefore, the objective of this presentation will be to ,make a mathematical model of the wingsuit physics and predict outcomes based on various scenarios
- We use well known aerodynamic laws

  to propose a glide equation for wingsuits

  .

FEASIBILITY

- The Bat-Glider is an airborne vehicle used by Batman. Inspired by Leonardo da Vinci's glider designs, it is used by Batman to glide through the sky without being noticed.
- But, this is not completely practical. Without a parachute, landing like batman will get you a broken leg and a twisted spine.
- This is because the velocities achieved during a flight are roughly around 100 MPH and without a parachute landing at that speed will be fatal.
- There has to be tail wing for stable flight but he doesn't have it in his suit.

FEASIBILITY

- And you can't keep gliding forever like Batman. The best known **gliding ratio** is just over 2:1.
- Glide ratio is an important parameter in determining how good a wingsuit design is.
    - Glide ratio = Horizontal Distance divided by the Change in Altitude.
- Aerodynamic drag prevents you from travelling long distances
- One method to increase the distance you cover is to use "Thrusters"
- Thrusters provide additional horizontal velocity and in some cases even lift.

FEASIBILITY

For Batman a few solutions are

* He could make his wing cape bigger

* He could land in a large pile of soft garbage

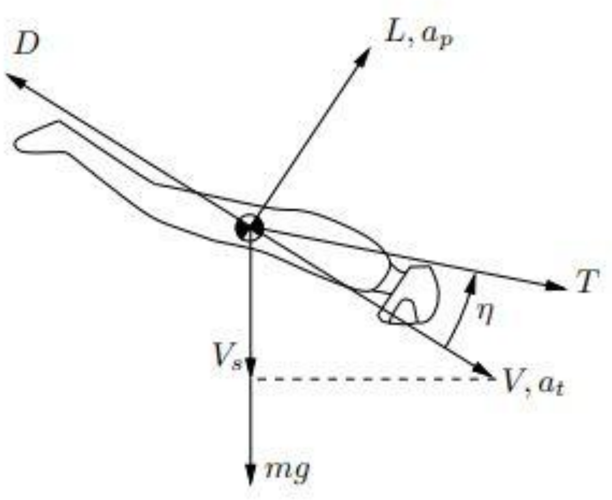
* He could fire a bat cable or bat bungee cord behind him to slow his forward speed from 100 mph

* He could control his jump so that he finishes by climbing up from near street level to 6 stories higher to use up the extra speed

* He could deploy some crash net or large crash bag in front of himself just before landing/crashing

* His suit/helmet could have crash resistance and he uses his skills to make the 100 mph crash non-fatal. Landing on a downward slope and into some amount of on the ground padding (bushes etc...)

FREE BODY DIAGRAM(FBD)



- L is the Lift
- T is the thrust*
- D is the overall drag force
- V_s is the Sinking velocity
- mg is the weight
- a_t and a_p are acceleration components
- V is the overall velocity.

MATHEMATICAL MODEL

- We consider only longitudinal flight, so two equations of motion are required. That along the flight path is
  - $mg(V_s/V) - D + T \cos\eta = ma_t$
- In the direction perpendicular to the flight path, the equation of motion is
  - $L - mg(1 - (V_s/V)^2)^{0.5} + T \sin\eta = ma_p$
- Drag can be considered of two types:
  - Induced drag
  - Parasitic drag

MATHEMATICAL MODEL

- The above drags can be modelled by the following equations:
  - $Di = L^2 /(c_i \rho V^2)$
  - $Dp = c_p \rho V^2$
- Here c_i and c_p are constants and can be found out using experimental analysis(we use linear regression to find out the values from given data)
- In these calculation we are assuming equilibrium flight .i.e, No accelerations and Thrust forces on the flying person.

MATHEMATICAL MODEL

- Solving the above equations we get :
  - $$V_s = \frac{V}{g}\left(\sqrt{A(A+2B)+g^2} - A\right)$$ where A = (c_iρV^2)/2m
    B = (c_pρV^2)/m

The equilibrium **glide ratio** is given by:

- **glide ratio =** $$\sqrt{\left(\frac{V}{V_s}\right)^2 - 1}$$

MATHEMATICAL MODEL

- We can relate coefficient of Drag and coefficient of Lift as:
  - $c_D = c_L$^2 *(1/c_i) + c_p
- From experimental data, we can get values for c_D and c_L. Using **Linear regression** we can get the straight line equation for c_D vs c_L^2 and compare the line equation.
- The slope of the line = 1/c_i and the intercept will be c_p

MatLab code for linear regression

```
X = [0.3,0.34,0.4,0.45,0.5];     % values of C_L^2
Y = [0.23,0.25,0.28,0.315,0.33];      % values of C_D
% elements of X and Y are obtained from  experimental data
n = 5;      % number of points taken

ssqx = sumsqr(X); % sum of squares of all elements of X
ssqy = sumsqr(Y); % sum of squares of all elements of Y
sp = sum(X*Y');    % sum of products of corresponding elements
ps = (sum(X))*(sum(Y)); % product of sum of each matrix

a1 = (n*sp - ps)/(n*ssqx - ssqy^2)
a0 = mean(X) - a1*mean(Y)


a1 =

    0.0173


a0 =

    0.3932
```

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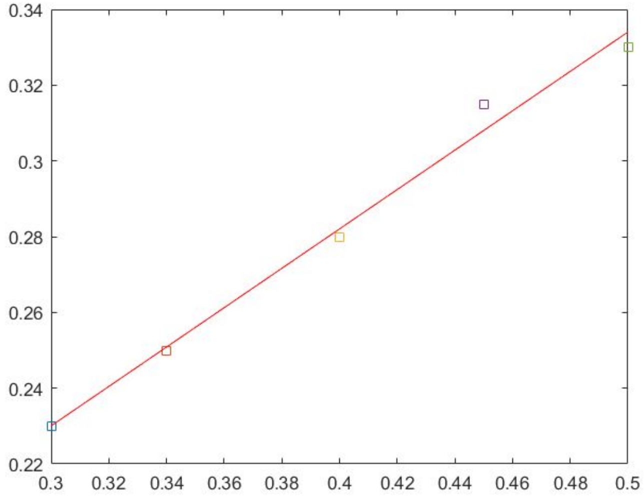
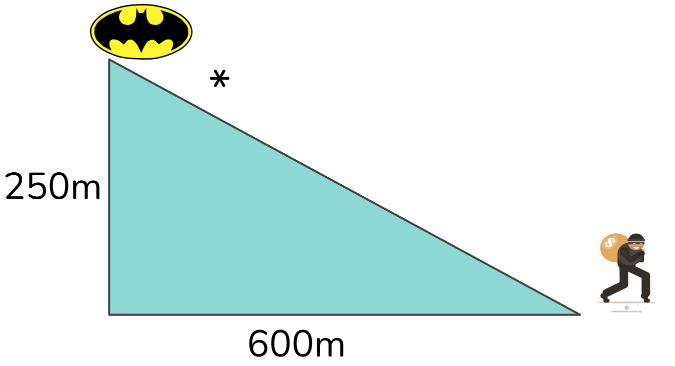


Analysis

- Imagine , Batman is standing on a 250m tall skyscraper, and a there is a thief at a distance of 600m from the building.
- Let's calculate at what speed should Batman launch himself to catch the thug.



Assumptions:

➔ The air has a constant density of 1.25 kg/m^3 and batman weighs about 100 kg (with suit) and g = 9.8 m/s^2.

➔ As soon as he launches he attains equilibrium/sustained flight

➔ c_i and c_p remain constant.

➔ c_L and c_D are obtained from experiments for similar conditions and Batman's cape area remains constant throughout flight.

*actual flight path shown later

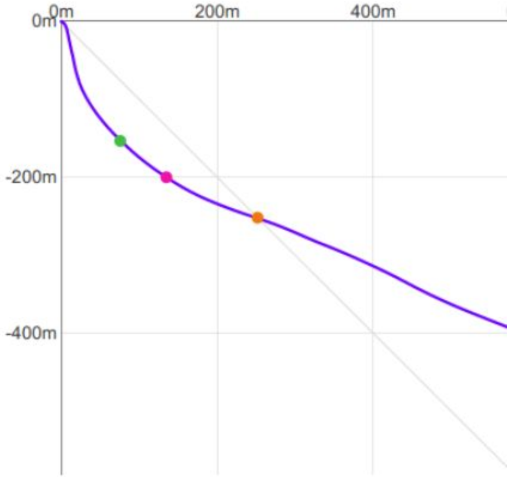
Analysis

- From the regression analysis we got c_i = 57.8 m^2 & c_p = 0.3932 m^2
- Here glide ratio = 600/250 = 2.4
- Equating it to the glide ratio equation from before,
  - $\sqrt{\left(\frac{V}{V_s}\right)^2 - 1}$ = 2.4 -----------(1)
- And also from the following equation:
  - $V_s = \frac{V}{g}\left(\sqrt{A(A+2B)+g^2} - A\right)$ --------------(2)
- Solving the above two equations we get V = 41 kmph

Analysis

- In the previous analysis we assume that sustained flight is reached as soon as he is launched.
- This is done for the simplicity of calculations for glide ratio and glide distance.
- A typical flight profile for base jumping is shown in the adjacent figure

- Here we can see that the person flies through a curved path before attaining sustained flight.
- Once sustained flight is reached, the flight path becomes almost linear with constant glide ratio and constant angle of attack.
- The green dot in the figure represents a gliding ratio of 1:1



Thrust requirements for level flight

- In order to fly like batman,we ought to attain a level flight.
  - Batman travels large distances with very little drop in altitude
- This can be modelled as a Levelled flight .i.e. no loss of altitude when flying.
- This cannot be achieved without the help of external sources like "Thrusters".
- This kind of design is called "powered wingsuit".

"The role of thrust in aviation is traditionally viewed as overcoming drag, but it can be beneficial to use some component of it to provide additional lift"

Thrust requirements for level flight

- We apply the thrust at an upward angle **'η'** from the flight path, as shown in the figure.(Refer slide 7)
- $\eta = \alpha + \chi$ ------> This equation gives the upward angle as a function of AoA(α) and a variable angle (χ) which will be fixed while deriving for levelled flight.
- From aerodynamic theory and linear regression the relation between lift coefficient and AoA is given as
  - $c_L = 1.17\alpha + 0.39$.
- Using this and the previously derived equations , and setting $\mathbf{V_s = 0}$ levelled flight we get
  - $T = \frac{m}{\sin(\eta)}\left(C - \sqrt{C^2 - g^2 - 2AB}\right)$ here A,B are as before and C = Acot(η)+g

- This is the thrust force required for our wingsuit for level flight.

REFERENCES

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Thank You!!!