Windcar

Problem

- Construct a car which is propelled solely by wind energy. The car should be able to drive straight into the wind. Determine the efficiency of your car.

Introduction

- Work devided in four parts

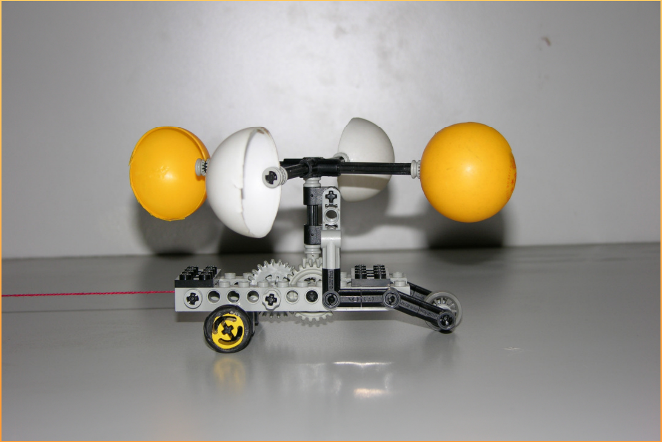
1. Vehicle construction

2. Wind turbines

3. Efficiency measuring

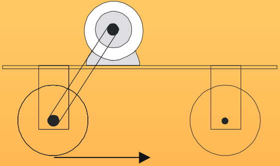
4. Determination of maximal working velocity

Vehicle construction.



- Gearbox ratio 1:12

Why is vehicle moving ?



- The internal forces can not change momentum of system
- Observing of motion is reduced to determination of external forces
- Sole external forces are friction forces
- Without slipping we have :

$$r\frac{d\omega}{dt} = a$$

- With wind powered vehicle everything is the same

Wind turbines

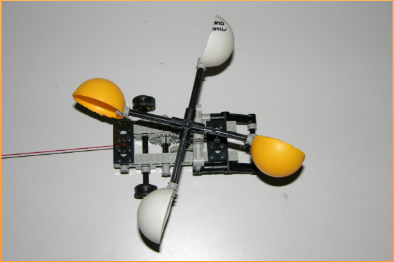
- We have two types of wind turbines vertical and horizontal axis
- In our case advantageous are vertical axis wind turbines

Vertical axis wind turbines

- Existing few types : Savonius, Dareius rotor and Cup Anemometer rotor
- Our research is based on Savonius and Cup anemometer rotor
- Dareius rotor desires pre-rotation

Cup Anemometer rotor

- Used in Anemometers
- Consists of four identical Half - spheres

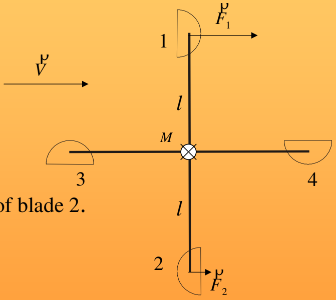


Which forces cause torque ?

- Force on a blade :

$$F = \frac{1}{2} C_x \rho v^2 S$$

ρ - Density
v - Wind Velocity
S - Blade Area
C_x - Drag coefficient



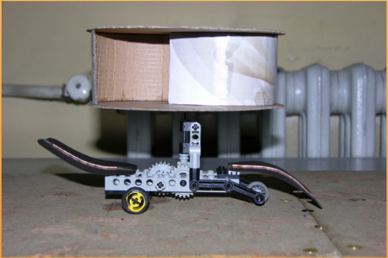
- C_x of blade 1. is 3 times greater then C_x of blade 2.
- Rotor is starting to rotate clockwise
- Torque equals to :

$$M = \frac{1}{2} l v^2 \rho S (C_x - C_y)$$

ρ - Density
v - Wind velocity
S - Blade area
C_x - Drag coefficient of blade 1.
C_y - Drag coefficient of blade 2.
l - Blade length

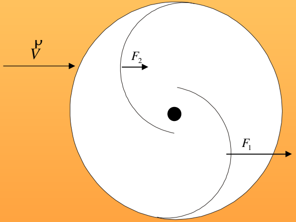
Savonius Rotor

- Used in water pumps
- There is a stream between blades



Savonius Rotor

- It is uncommon
- Force configuration is the same sa Anemo
- There is stream between blades
- That stream increases efficiency at high angular velocities



- There is drag force acting on a Rotor in wind stream

$$D \approx \frac{1}{2}\rho v^2 C_t S_1$$

ρ - Density
v - Wind velocity
S_1 - Rotor cross section area
C_t - Drag coefficient of whole rotor

Efficiency determination

Determination of wind power

- Wind kinetic energy :

$$E_{kv} = \frac{1}{2} m v^2 = \frac{1}{2} (\rho A v t) v^2 = \frac{1}{2} \rho A t v^3$$

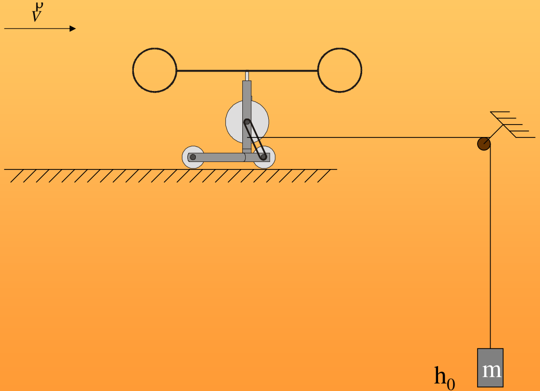
ρ - density
v - Wind velocity
A - Crosssectional area of blade
t - Time

- Wind power :

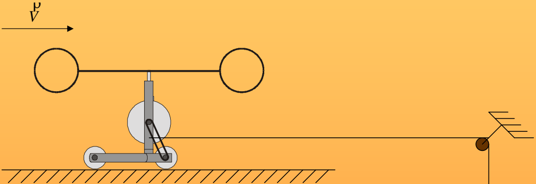
$$P_v = \frac{dE}{dt} = \frac{1}{2} \rho A v^3$$

ρ - Density
v - Wind velocity
A - Cross sectional area of blade

Wind power measurment

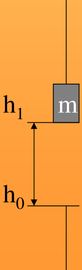


Wind power measurment

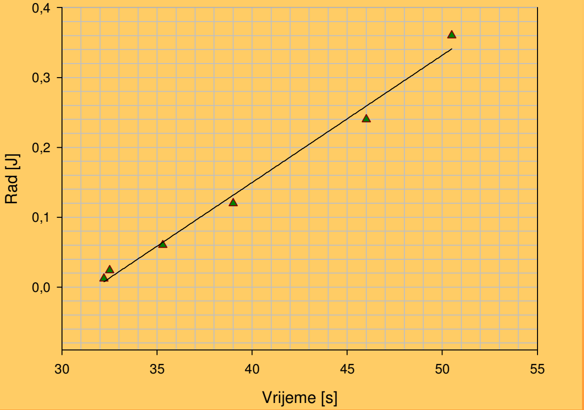


$$W = \Delta E_p = mg(h_1 - h_0)$$

$$P_a = \frac{dW}{dt} = \frac{mg(h_1 - h_0)}{\Delta t}$$

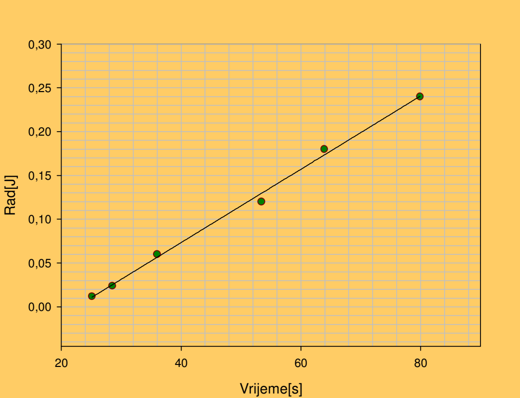


Efficiency determination "Cup anemo"



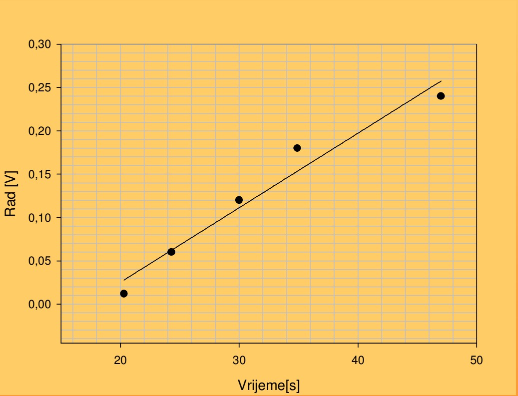
$$P_a = \frac{dW}{dt} = 0{,}018W \qquad P_v = 0{,}135W \qquad \eta = C_p = 0{,}133 = 13{,}3\%$$

Efficiency determination “Savonius” 4m/s



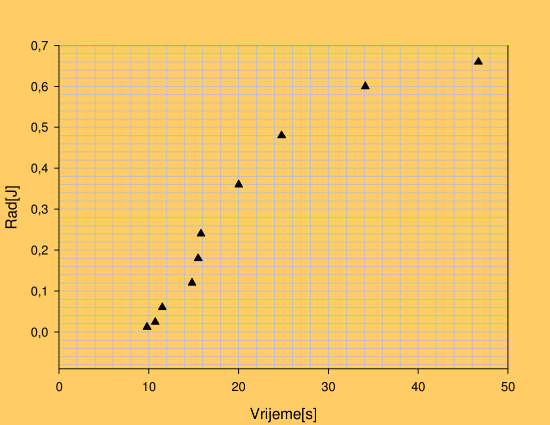
$P_v = 0{,}096W$ $P_a = \frac{dW}{dt} = 0{,}0043W$ $\eta = C_p = 0{,}044 = 4.4\%$

Efficiency determination “Savonius” 5m/s



$$P_a = 0.043W$$

Power measurment “Savonius” 7m/s



Determination of maximal working velocity

Determination of maximal working velocity

- It is wind velocity at which the vehicle stops working
- Slipping Starts
- There are few methods of increasing maximal velocity :

- Vehicle mass increasing
- Adding downforce wings “spoilers”

Influence of vehicle mass to max. wind working velocity

- While vehicle is accelerating straight into the wind equation of motion is :

$$m\frac{dv}{dt} = F_t - F_n = \frac{Me}{r} - F_n$$

M - Rotor Torque
e - Gearbox Ratio
r - Motor Wheels radius
F_n - Friction force on other wheels

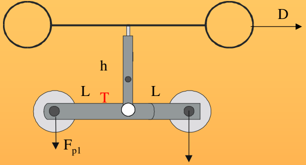
- The condition for acceleration without slipping is :

$$\frac{Me}{r} \leq \mu F_p$$

F_p - motor wheels pressure force
μ - fricion cofficient on motor wheels

Wheels pressure force

- Without rotor drag Forces are :



$$F_{p1} = F_p = \frac{m}{2} g$$

- Drag force causes torque in point T

$$M_D = Dh$$

- Now pressure forces are :

$$F_p = \frac{1}{2} mg + \frac{hD}{L} \qquad F_{p1} = \frac{1}{2} mg - \frac{hD}{L_1}$$

Max. Velocity as a function of vehicle parameters

- By inserting in slipping Condition and solving for v we have :

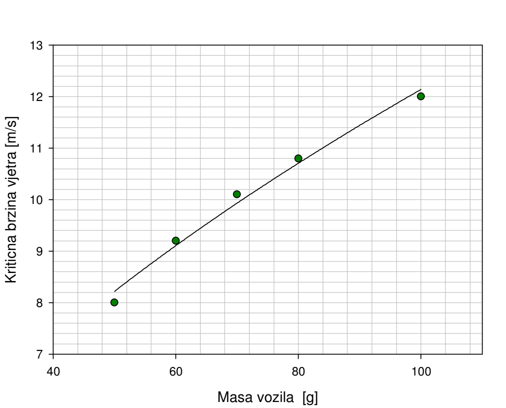
$$v_g = \sqrt{\frac{\mu_1 r(Lmg + 2hD)}{elL\rho SC_x}}$$

μ_1 - motor wheels friction coefficient
e - gearbox ratio
r - Motor wheels ratio
m - Vehicle mass
S - Blade area
ρ - Air density
h - visina hvatišta turbine
C_x - blade drag coefficient
L - distance between motor wheels and point T

- From equation follows :

$$v = \sqrt{am + b}$$

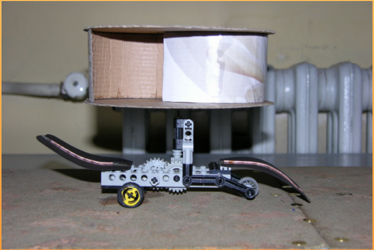
Experimental test of equation



• Congruence is relatively good with respect to our simple Theoretical model

Influence of downforce wings on max. working velocity

- Wings increase pressure forces on wheels
- Wings also increases cross sectional area of whole vehicle



Masa=50g	Bez zakrilca	Prednja zakrilca	Stražnja zakrilca	Sva zakrilca
Gran.Brzina	8 m/s	7.7 m/s	8.5 m/s	9.1 m/s

Conclusion

- Vehicle powered solely by wind energy is constructed
- Research was made on “Cup anemo” and “Savonius” rotors
- Vehicle efficiency with “Cup anemo” is 13.3%
- Vehicle efficiency with “Savonius rotor” is 4.4%
- For savonius rotor eeeiciency is function of angular velocity
- Dependence of max. working velocity on vehicle parameters is determined
- Influence of downforce wings is lower then expected
- Maximal achived working velocity 12 m/s