ME/ESE 4470
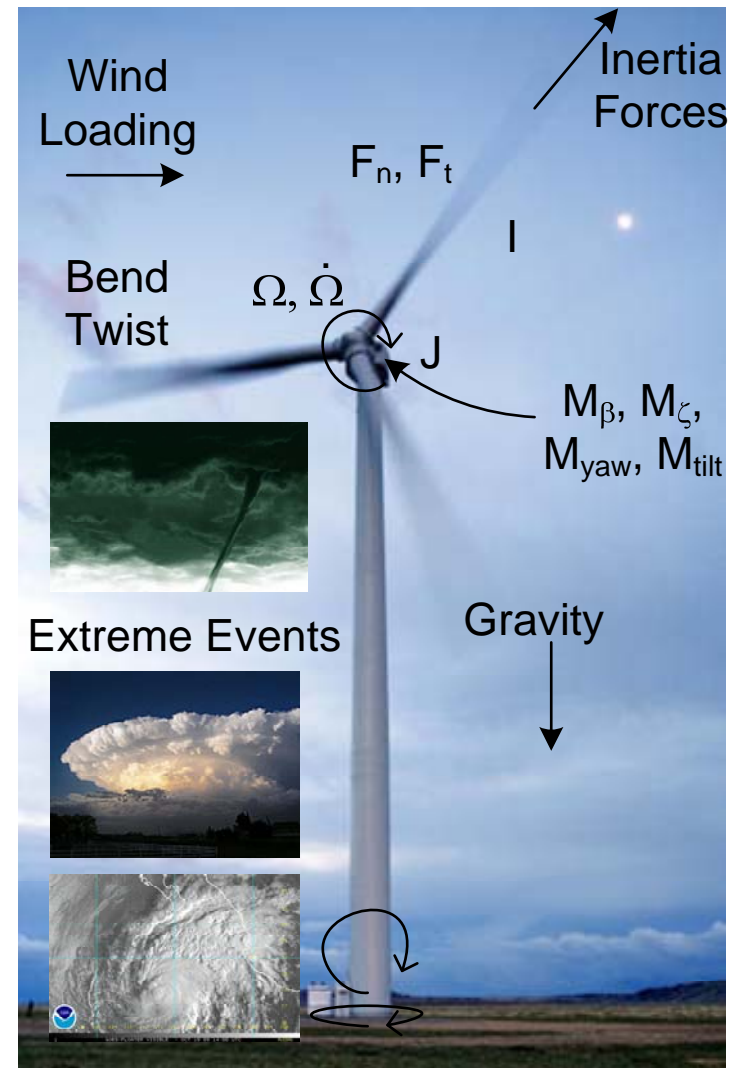# Wind and Tidal Power
Mechanics
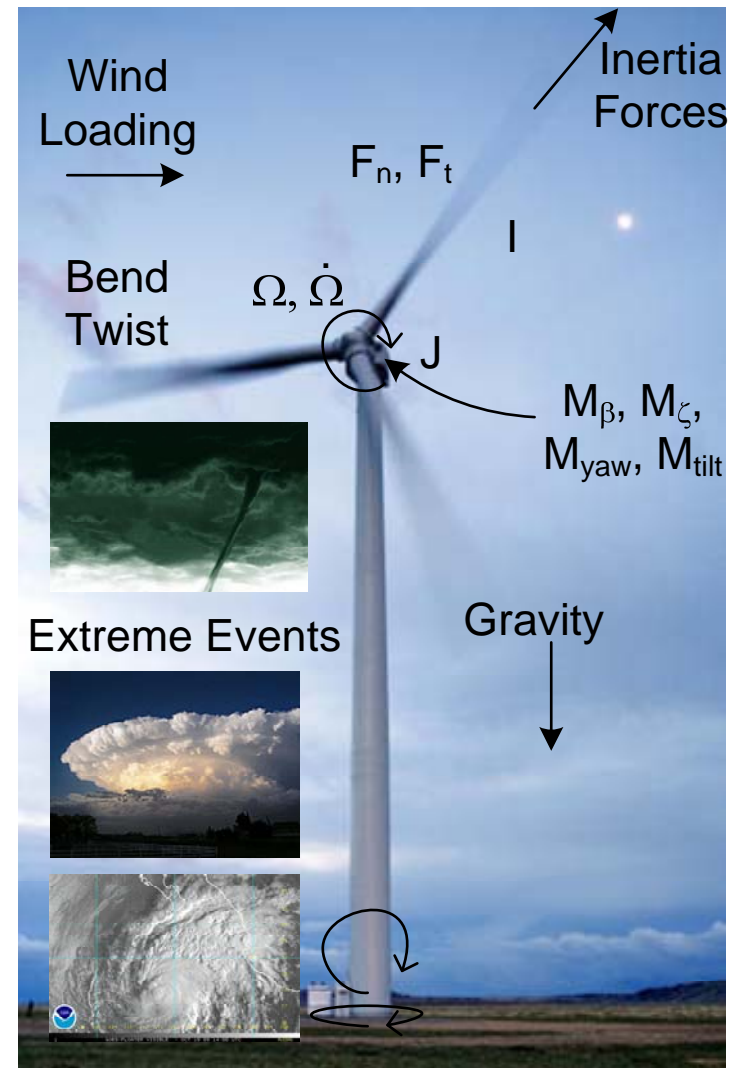
Wind Turbine Mechanics

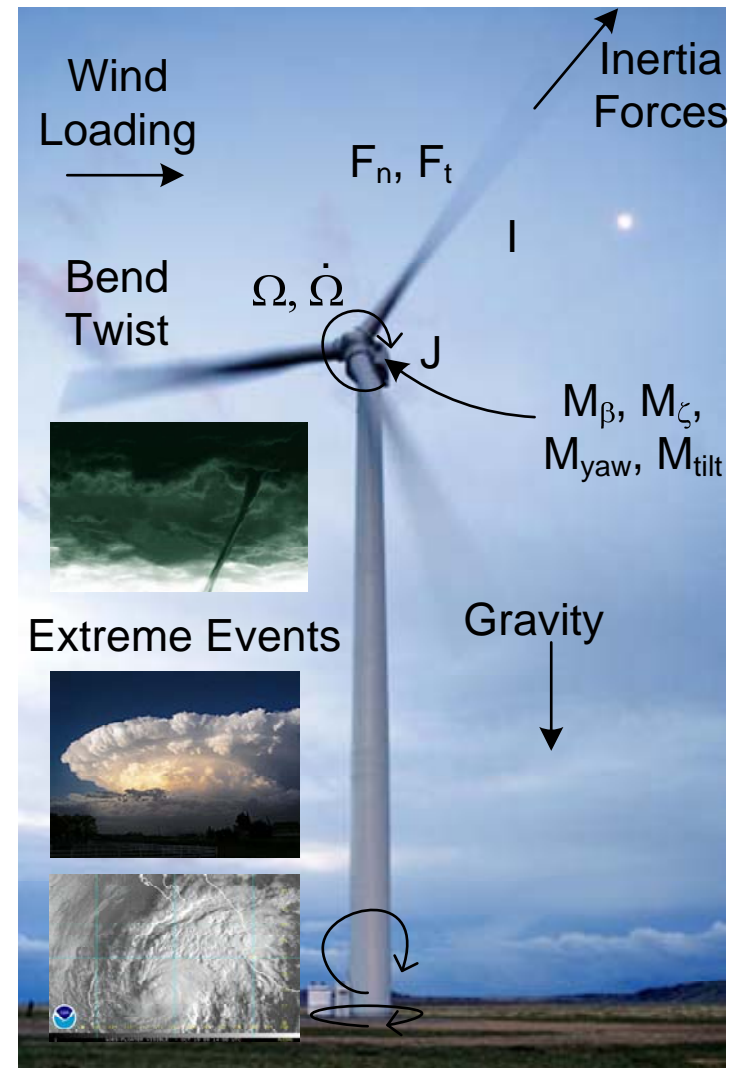## A. Introduction

Wind Turbine Mechanics

A. Introduction

Wind Loading
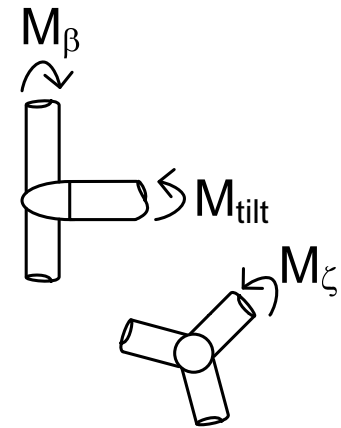
F_n, F_t

Bend Twist

$\Omega, \dot{\Omega}$

Inertia Forces

I

J

M_β, M_ζ, M_{yaw}, M_{tilt}

Extreme Events

Gravity

Wind Turbine Mechanics

A. Introduction

Wind Loading

F_n, F_t

Bend Twist

$\Omega, \dot{\Omega}$

J

I

Inertia Forces

M_β, M_ζ, M_{yaw}, M_{tilt}

Extreme Events

Gravity

Wind Turbine Mechanics

B. Wind Turbine Loads

1. Primary Loads

M_β

M_{tilt}

M_ζ

Wind Turbine Mechanics

B. Wind Turbine Loads

   1. Primary Loads

M_β

M_{tilt}

M_ζ

Wind Turbine Mechanics

B. Wind Turbine Loads

    1. Primary Loads

M_β

M_{tilt}

M_ζ

M_{yaw}
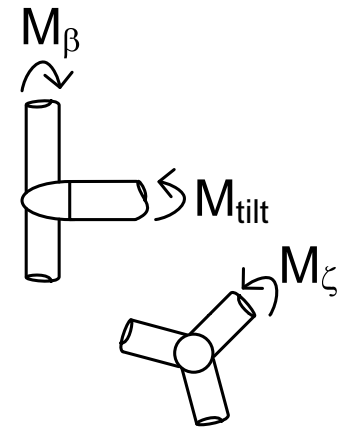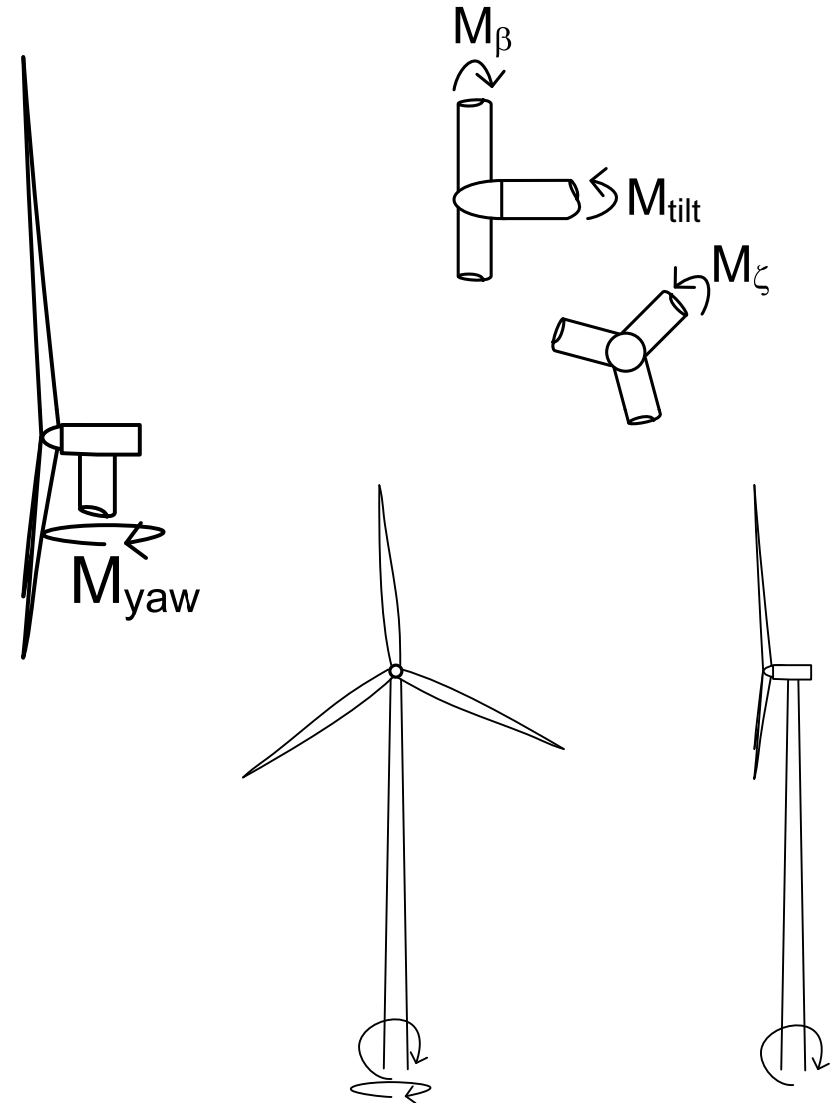
Wind Turbine Mechanics

B. Wind Turbine Loads

2. Sources of Load

    a. Gravitational Loads
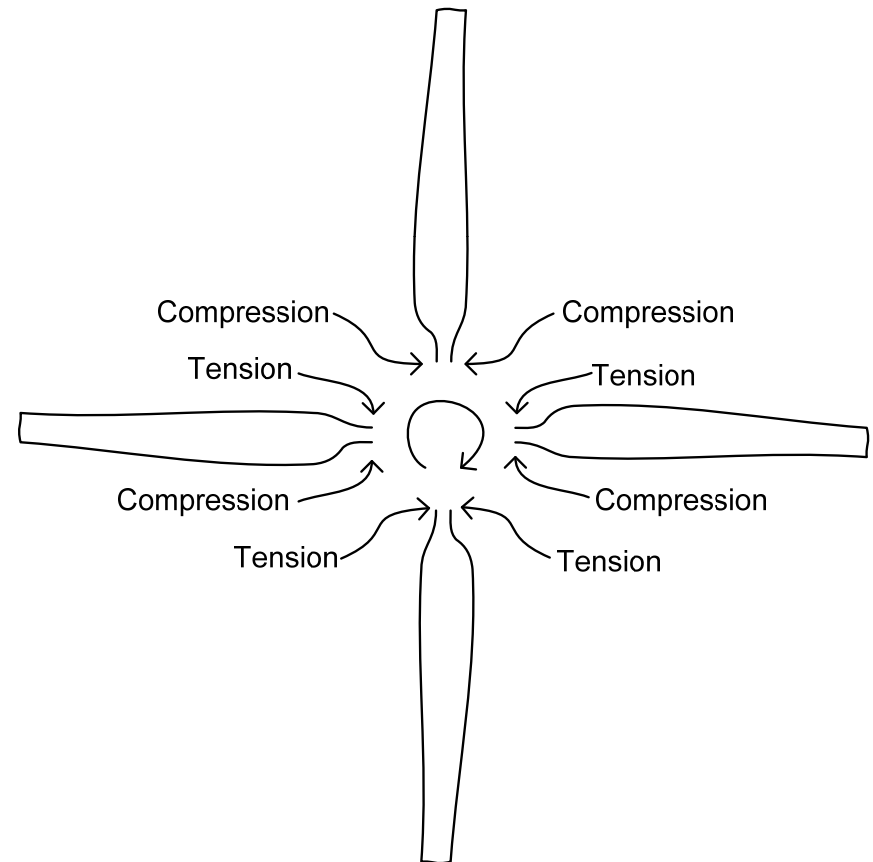
Compression

Compression

Tension

Tension

Compression

Compression

Tension

Tension

Wind Turbine Mechanics

B. Wind Turbine Loads

    2. Sources of Load

        b. Inertial Loads

dr $\longrightarrow$ dF$_i$

r

dF$_c$

dr

r

Wind Turbine Mechanics

B. Wind Turbine Loads

2. Sources of Load

b. Inertial Loads

F_c

$F_{c,r}$
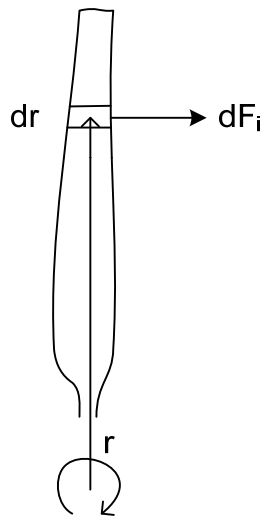
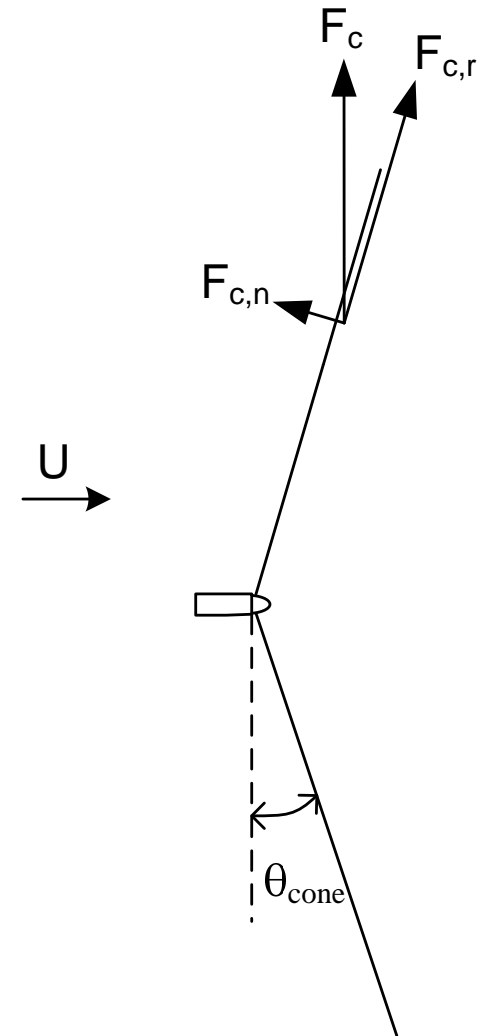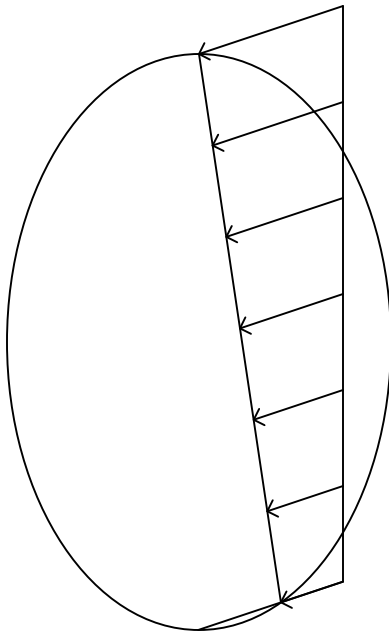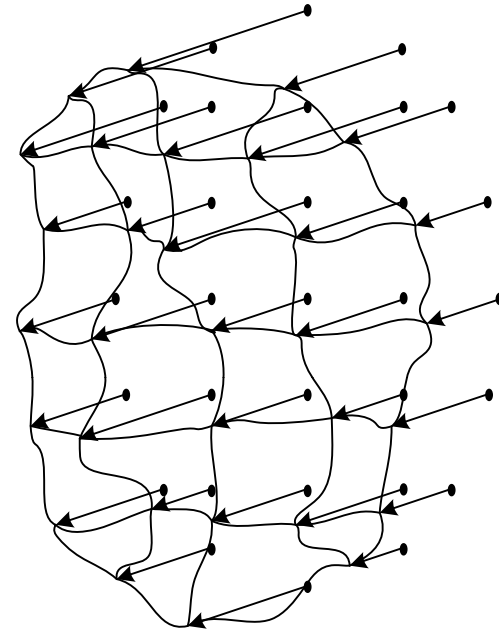$F_{c,n}$

U

θ_{cone}
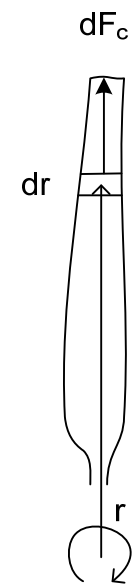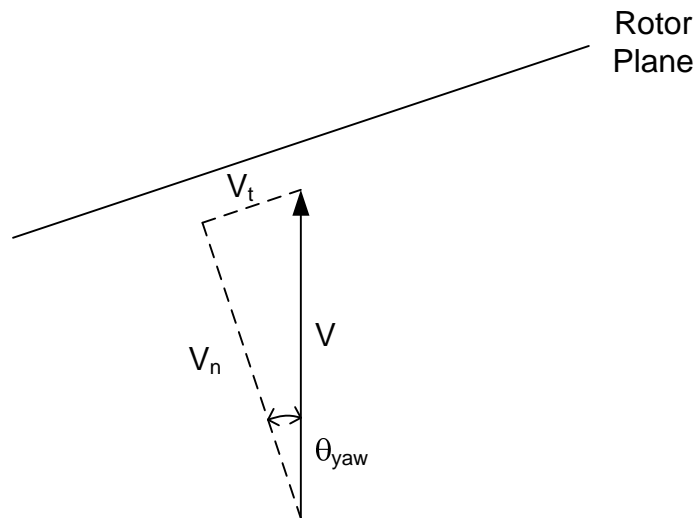
Wind Turbine Mechanics

B.   Wind Turbine Loads

   2.   Sources of Load

      c.   Aerodynamic Loading

Wind Turbine Mechanics

B. Wind Turbine Loads

    2. Sources of Load

        c. Aerodynamic Loading

Rotor
Plane

V_t

V

V_n

θ_{yaw}

Wind Turbine Mechanics
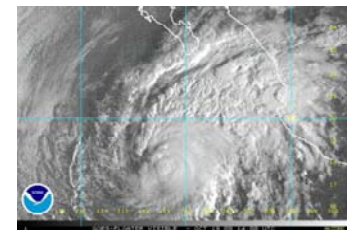
B.   Wind Turbine Loads

   2.   Sources of Load

      c.   Aerodynamic Loading

Extreme Events

Wind Turbine Mechanics

B.   Wind Turbine Loads
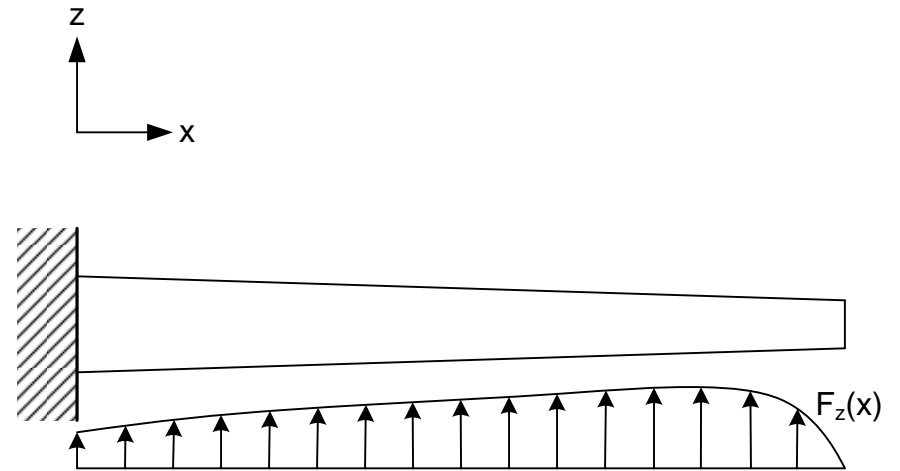
   3.   Cyclic Loads and Fatigue

Wind Turbine Mechanics

B.   Wind Turbine Loads

    3.   Cyclic Loads and Fatigue

Wind Turbine Mechanics

C. Static and Dynamic Modeling of Wind Turbines

Wind Turbine Mechanics

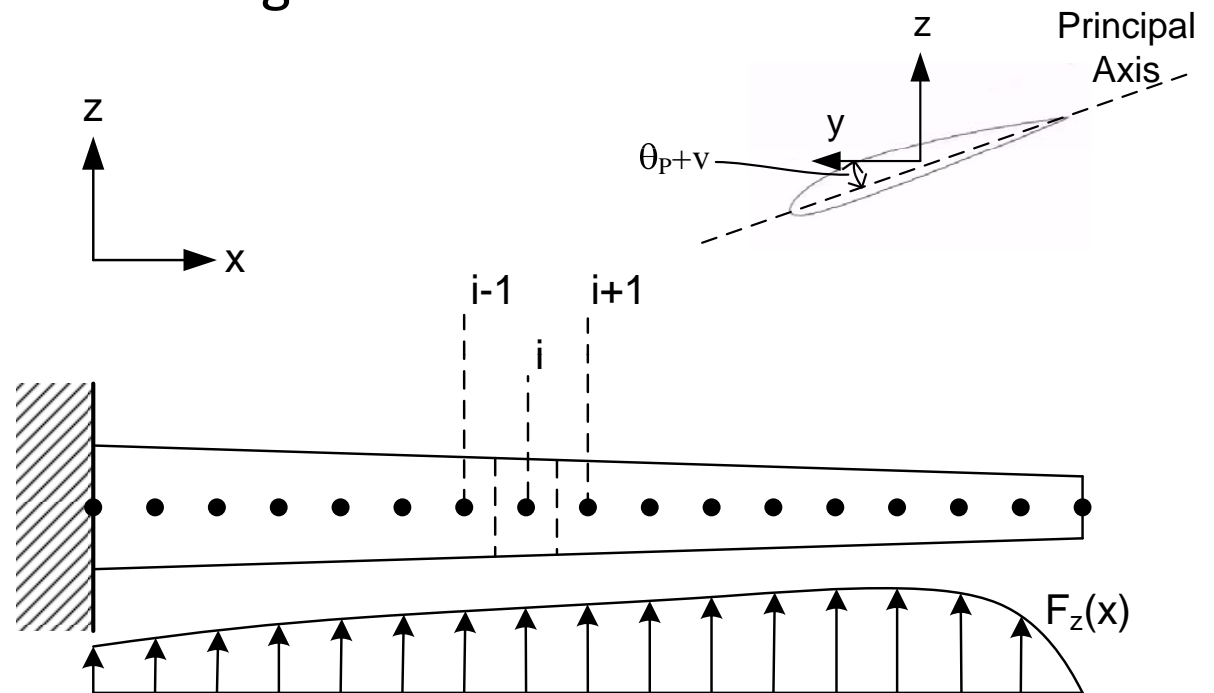C. Static and Dynamic Modeling of Wind Turbines

Wind Turbine Mechanics

C. Static and Dynamic Modeling of Wind Turbines

Wind Turbine Mechanics

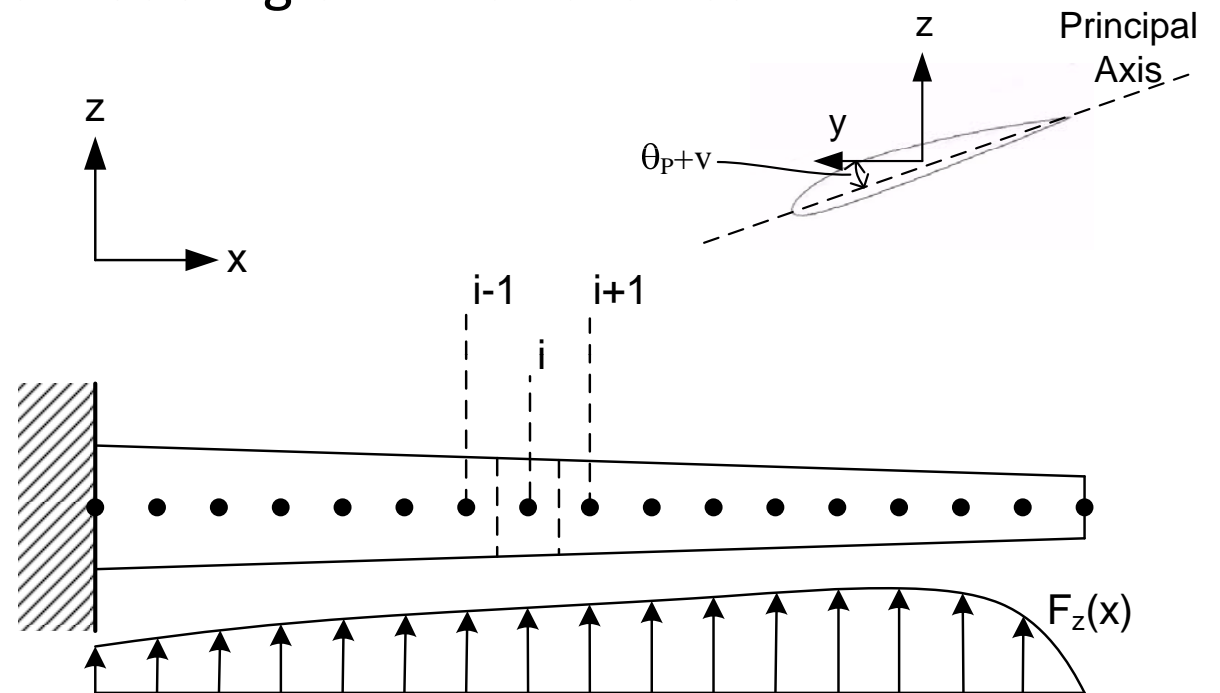C. Static and Dynamic Modeling of Wind Turbines

    1. Beam Theory

$$M_y \quad \left(\quad T_z \quad \right| \quad \middle| \quad T_z + \frac{dT_z}{dx}dx \quad \right) \quad M_y + \frac{dM_y}{dx}dx$$

Wind Turbine Mechanics

C. Static and Dynamic Modeling of Wind Turbines
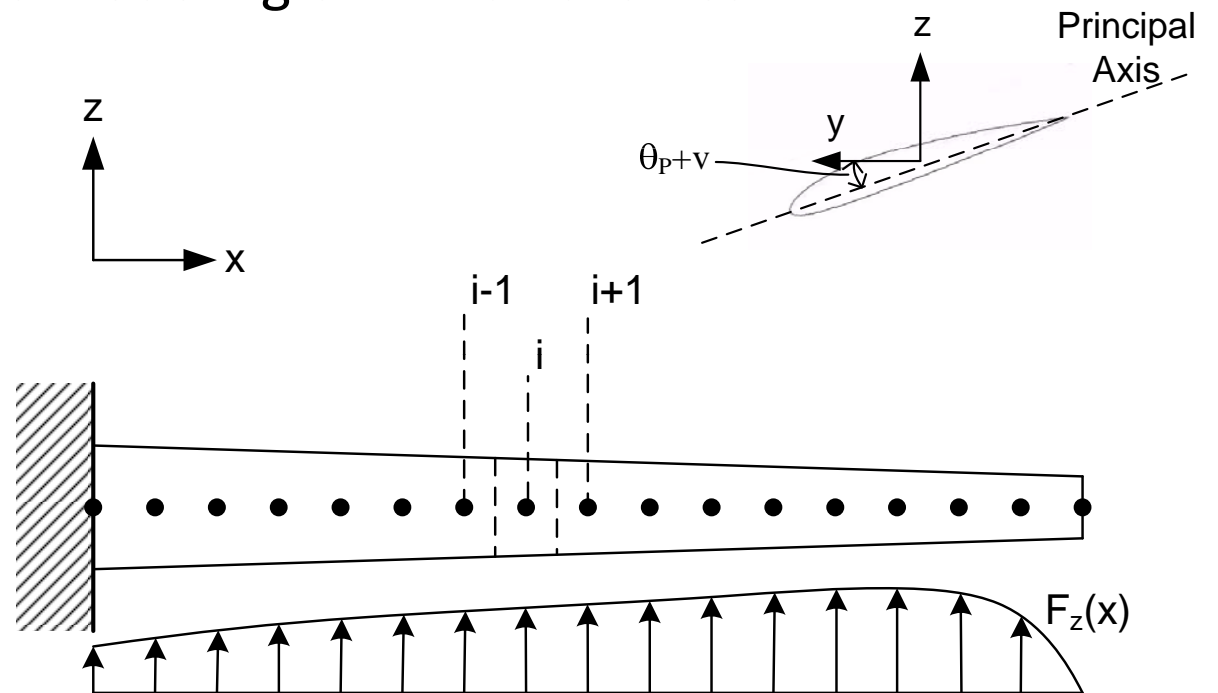
   1. Beam Theory

Wind Turbine Mechanics

C. Static and Dynamic Modeling of Wind Turbines

   1. Beam Theory

Wind Turbine Mechanics

C. Static and Dynamic Modeling of Wind Turbines

    1. Beam Theory

Wind Turbine Mechanics

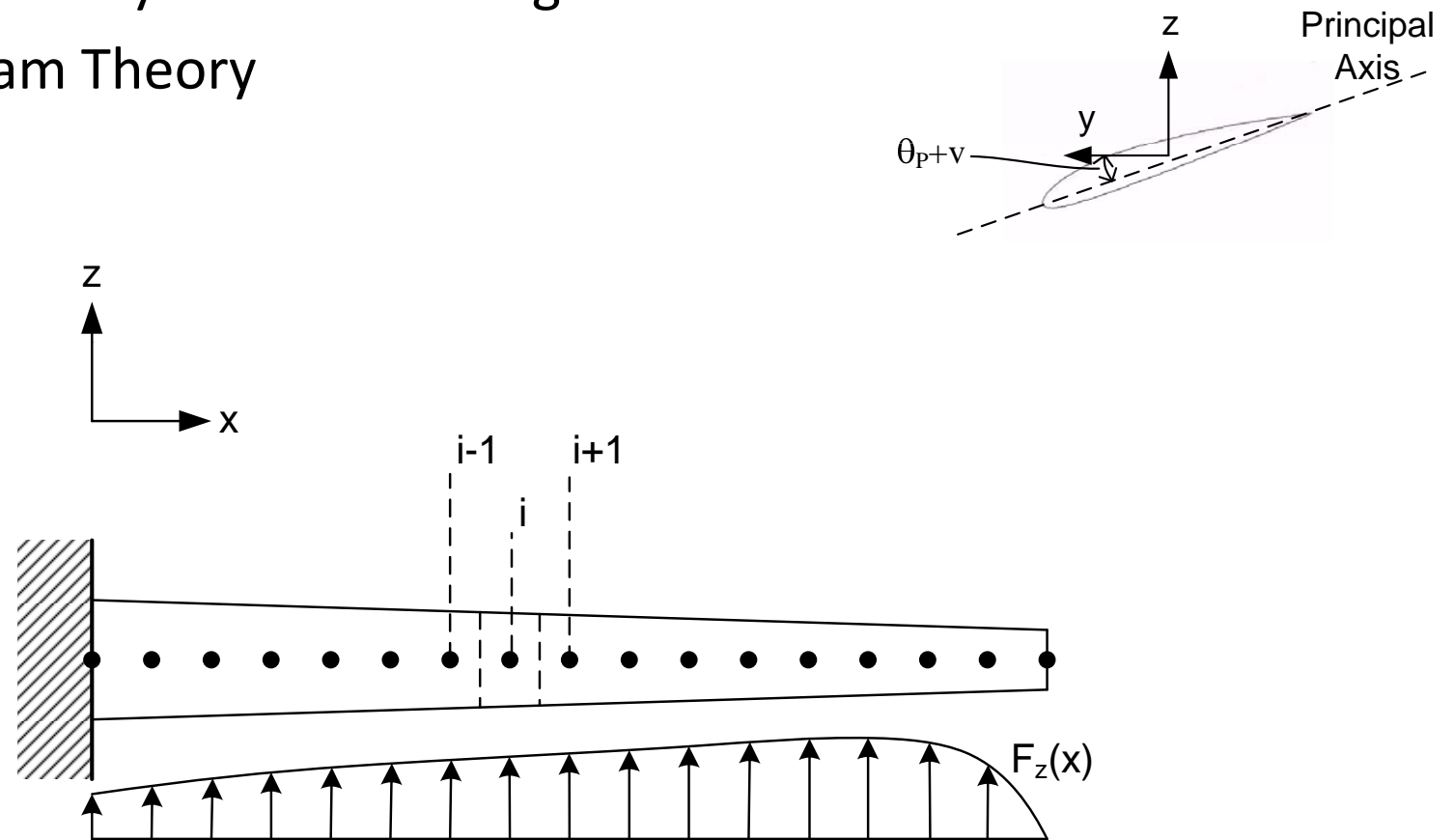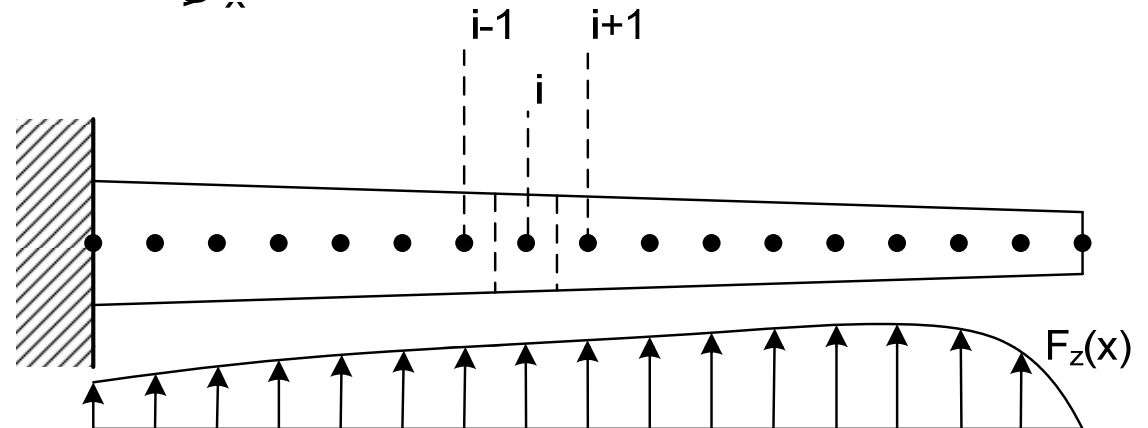C. Static and Dynamic Modeling of Wind Turbines

  1. Beam Theory

$$T_y^{i-1} = T_y^i + \frac{1}{2}(F_y^{i-1} + F_y^i)(x^i - x^{i-1})$$

$$T_z^{i-1} = T_z^i + \frac{1}{2}(F_x^{i-1} + F_x^i)(x^i - x^{i-1})$$
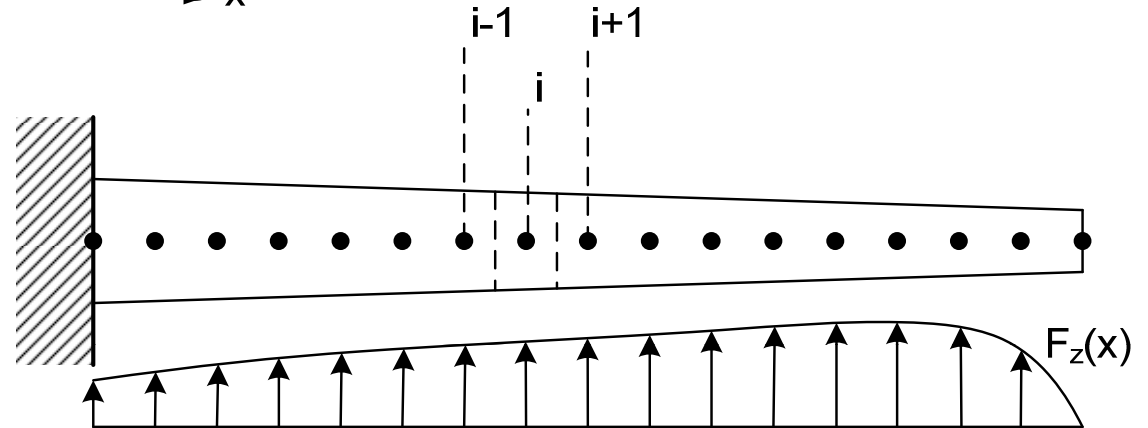
$$M_y^{i-1} = M_y^i - T_z^i(x^i - x^{i-1}) - \left(\frac{1}{6}F_z^{i-1} + \frac{1}{3}F_z^i\right)(x^i - x^{i-1})^2$$

$$M_z^{i-1} = M_z^i + T_y^i(x^i - x^{i-1}) + \left(\frac{1}{6}F_y^{i-1} + \frac{1}{3}F_y^i\right)(x^i - x^{i-1})^2$$

Wind Turbine Mechanics

C. Static and Dynamic Modeling of Wind Turbines

   1. Beam Theory

$$\theta_y^{i+1} = \theta_y^i + \frac{1}{2}(\kappa_y^{i+1} + \kappa_y^i)(x^{i+1} - x^i)$$

$$\theta_z^{i+1} = \theta_z^i + \frac{1}{2}(\kappa_z^{i+1} + \kappa_z^i)(x^{i+1} - x^i)$$

$$u_y^{i+1} = u_y^i + \theta_z^i(x^{i+1} - x^i) + \left(\frac{1}{6}\kappa_z^{i+1} + \frac{1}{3}\kappa_z^i\right)(x^i - x^{i-1})^2$$

$$u_z^{i+1} = u_z^i + \theta_y^i(x^{i+1} - x^i) + \left(\frac{1}{6}\kappa_y^{i+1} + \frac{1}{3}\kappa_y^i\right)(x^i - x^{i-1})^2$$
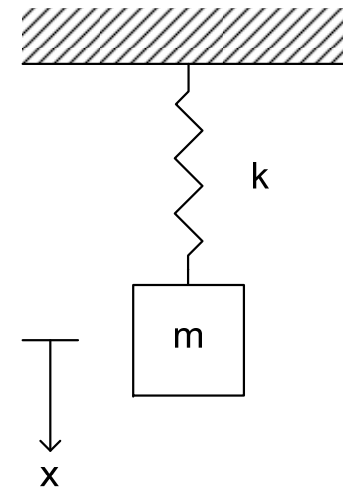
Wind Turbine Mechanics

C. Static and Dynamic Modeling of Wind Turbines

    2. Dynamic Modeling

Wind Turbine Mechanics

C. Static and Dynamic Modeling of Wind Turbines

    2. Dynamic Modeling

Wind Turbine Mechanics

C. Static and Dynamic Modeling of Wind Turbines

   2.   Dynamic Modeling

Wind Turbine Mechanics
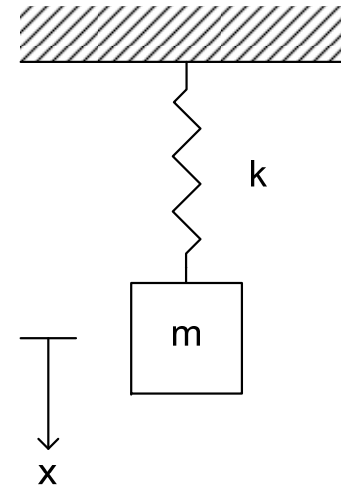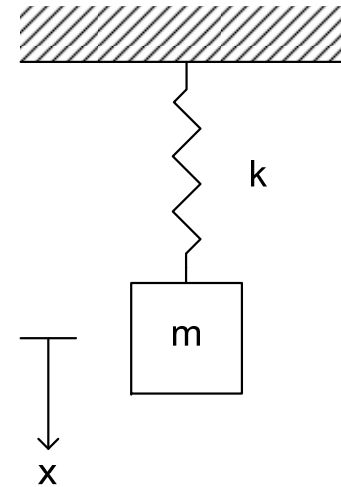
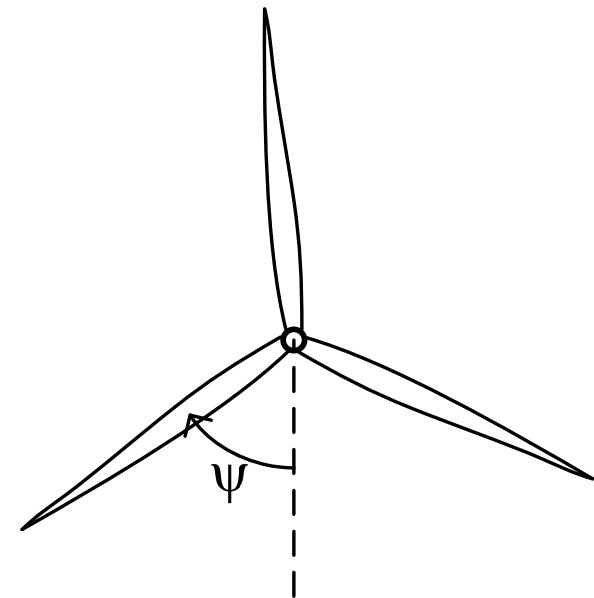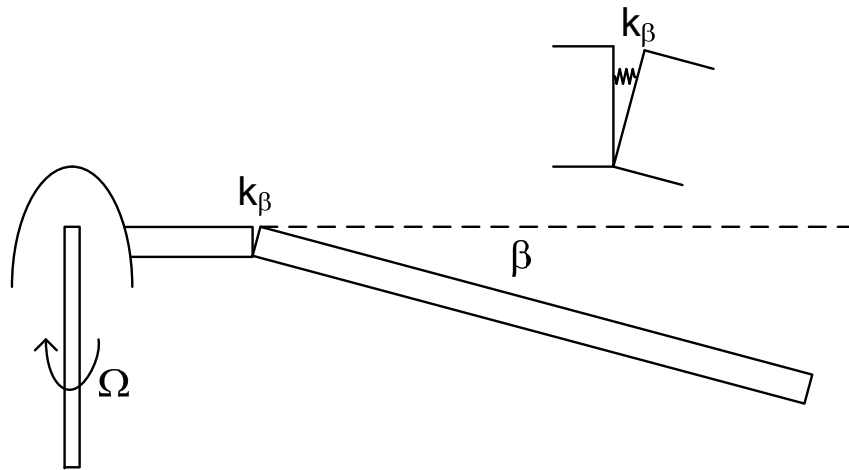C. Static and Dynamic Modeling of Wind Turbines

    2. Dynamic Modeling

Wind Turbine Mechanics

C. Static and Dynamic Modeling of Wind Turbines

    2. Dynamic Modeling

Wind Turbine Mechanics

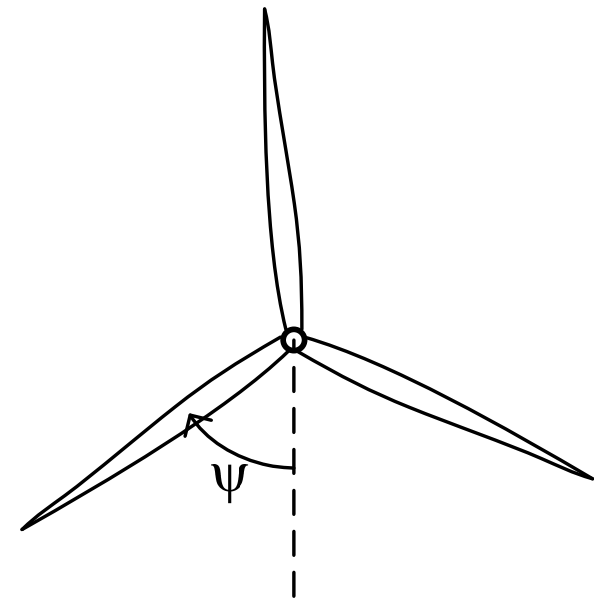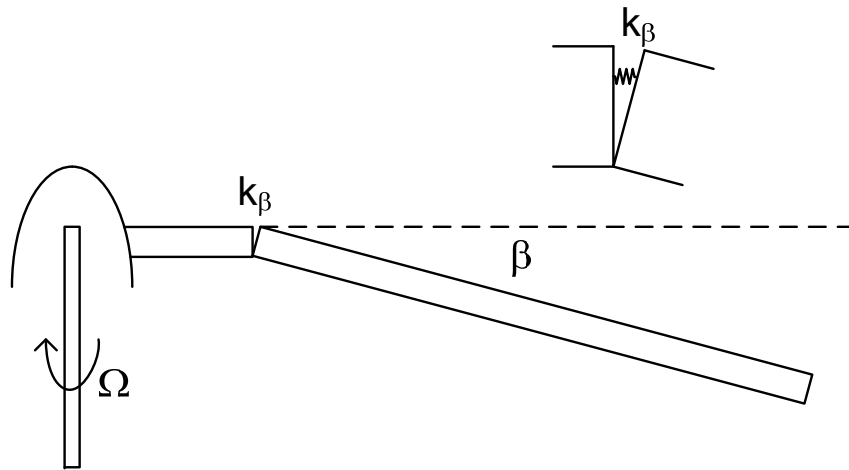C. Static and Dynamic Modeling of Wind Turbines

    2. Dynamic Modeling

Wind Turbine Mechanics

C. Static and Dynamic Modeling of Wind Turbines

    2. Dynamic Modeling

Wind Turbine Mechanics

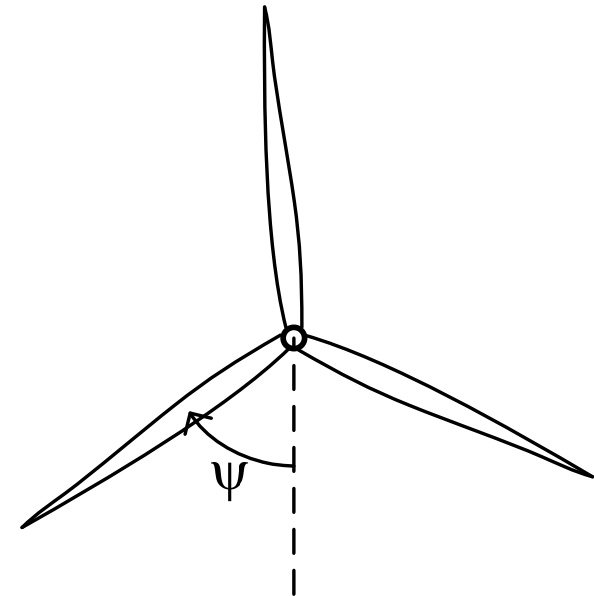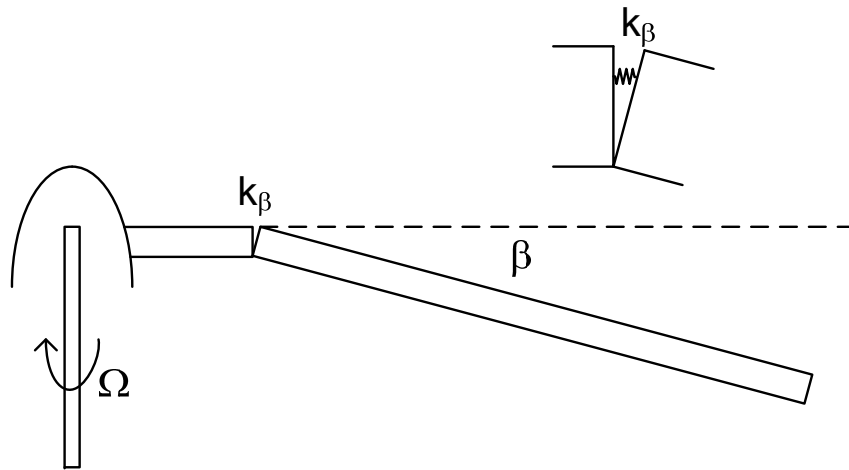C.   Static and Dynamic Modeling of Wind Turbines

    2.   Dynamic Modeling