Wind Turbine Mechanics

C. Static and Dynamic Modeling of Wind Turbines

2. Dynamic Modeling

GENERAL FORM OF DYNAMIC EQUATION (INERTIA, DAMPING, RESTORING, FORCING)

$$\ddot{\beta} + C\dot{\beta} + K\beta = F(t)$$

AFTER ACCOUNTING FOR FORCES WE'VE DISCUSSED

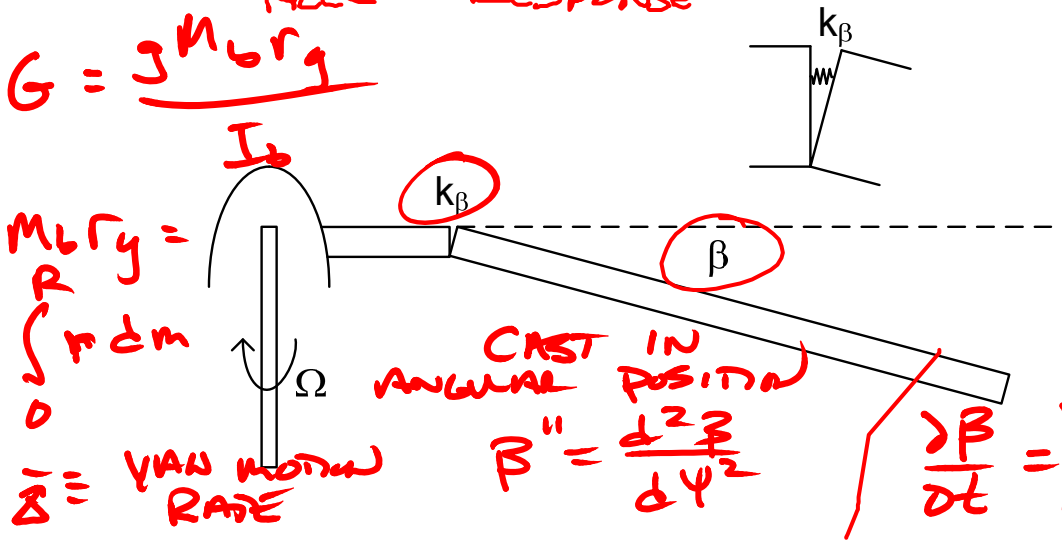
$$\beta'' + \left[\underbrace{1+\epsilon}_{\text{CENTRIFUGAL}} + \underbrace{\frac{G}{\Omega^2}\cos\psi}_{\text{GRAVITY}} + \underbrace{\frac{k_\beta}{\Omega^2 I_b}}_{\text{BLADE SPRING}}\right]\beta = \underbrace{\frac{M_\beta}{\Omega^2 I_b}}_{\text{AERODYNAMIC LOADS}} \underbrace{-2\bar{\delta}\cos(\psi)}_{\text{YAW MOTION}}$$

FREE RESPONSE | FORCING

$$G = \frac{g M_b r_g}{I_b}$$

$$M_b r_y = \int_0^R r\,dm$$

$\bar{\delta}$ = YAW MOTION RATE



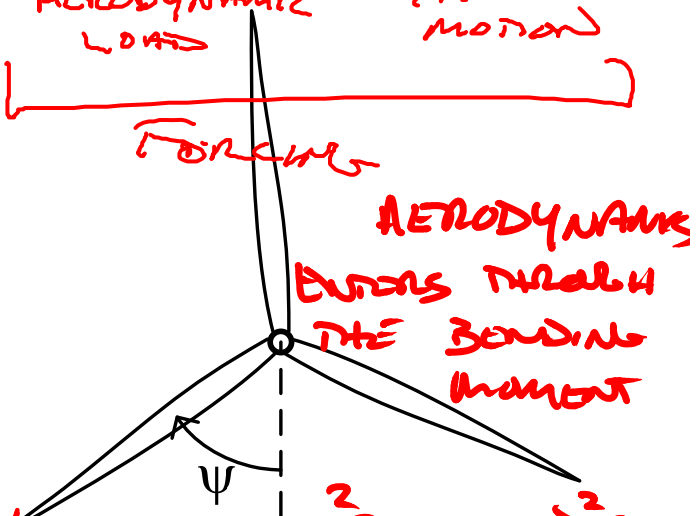
CAST IN ANGULAR POSITION

$$\beta'' = \frac{d^2\beta}{d\psi^2}$$

$$\frac{\partial\beta}{\partial t} = \frac{\partial\beta}{\partial\psi}\frac{\partial\psi}{\partial t} = \Omega\frac{\partial\beta}{\partial\psi}$$

$$\frac{\partial^2\beta}{\partial t^2} = \Omega^2\frac{\partial^2\beta}{\partial\psi^2}$$

AERODYNAMIC LOADS THROUGH THE BENDING MOMENT



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NOTE THAT AERODYNAMICS GENERATES A TERM PROPORTIONAL TO $\dot{\beta}$ ← AERODYNAMIC DAMPING TERM

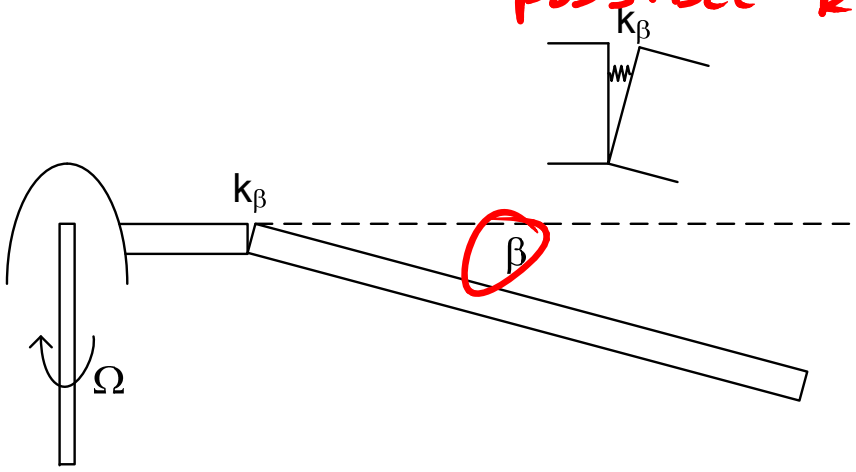
SOLUTION → GIVEN AERODYNAMIC LOAD & YAW RATE ← CONVERT TO FUNCTION OF ψ

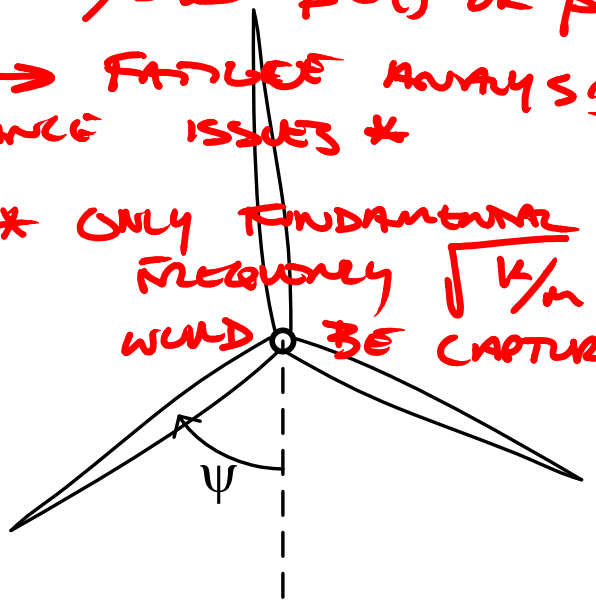
EQUATIONS MAY BE SOLVED TO YIELD $\beta(\psi)$ OR $\beta(t)$

FROM $\beta(\psi)$ → FLUCTUATING LOADS → FATIGUE ANALYSIS

POSSIBLE RESONANCE ISSUES *

* ONLY FUNDAMENTAL FREQUENCY $\sqrt{k/m}$ WOULD BE CAPTURED





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ACTUAL MODELING APPROACHES ARE SIMILAR, BUT MORE COMPLEX

FAST

SIMILAR "SPRING" MODELS USED

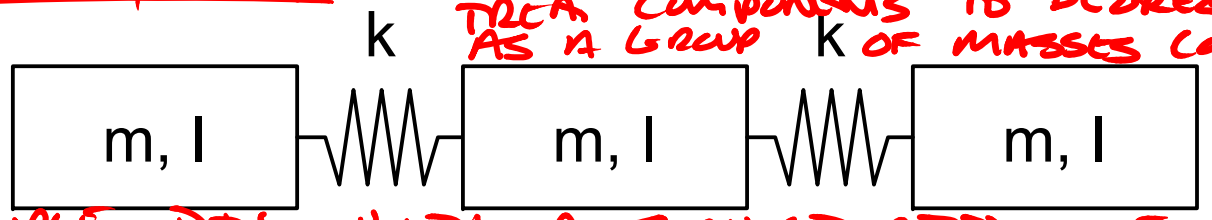
→ MULTIPLE DOF NOW INCLUDED FOR BLADE
1ST & 2ND FW BENDING MODES
1ST EDGEWISE BENDING MODE

→ INCLUDE OTHER COMPONENTS
TOWER
YAW
DRIVE TRAIN
} MULTIPLE MODES FOR EACH

ADAMS

MULTIBODY DYNAMICS

TREAT COMPONENTS TO DEGREE NECESSARY AS A GROUP OF MASSES CONNECTED BY SPRINGS



TURBSIM

COUPLE THIS WITH A SOPHISTICATED INFLOW & AERODYNAMIC MODELS ← AERODYN