Wind Turbine Mechanics

A. Introduction

FOCUS HAS BEEN ON

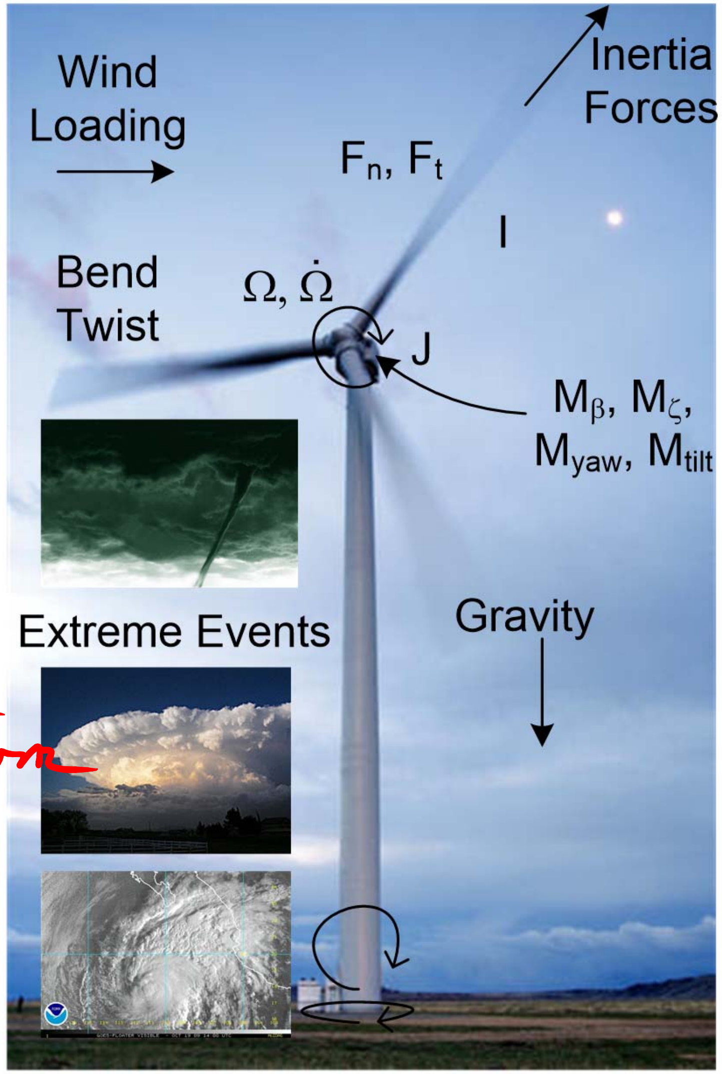
→ HOW MUCH ENERGY CAN WE EXTRACT FROM WIND?

NOW WE MUST CONSIDER

→ WIND TURBINE MUST BE STRUCTURALLY SOUND

→ MUST BE EFFECTIVE AT TURNING ENERGY OR POWER IN THE WIND INTO ROTATIONAL ENERGY / POWER

→ ALL OF THIS MUST BE ACCOMPLISHED AT A REASONABLE COST



Wind Turbine Mechanics

A. Introduction

TO ADDRESS THESE ISSUES

CONSIDER WIND TURBINE MECHANICS

FORCES, MOMENTS & MOTION

STATIC & DYNAMIC

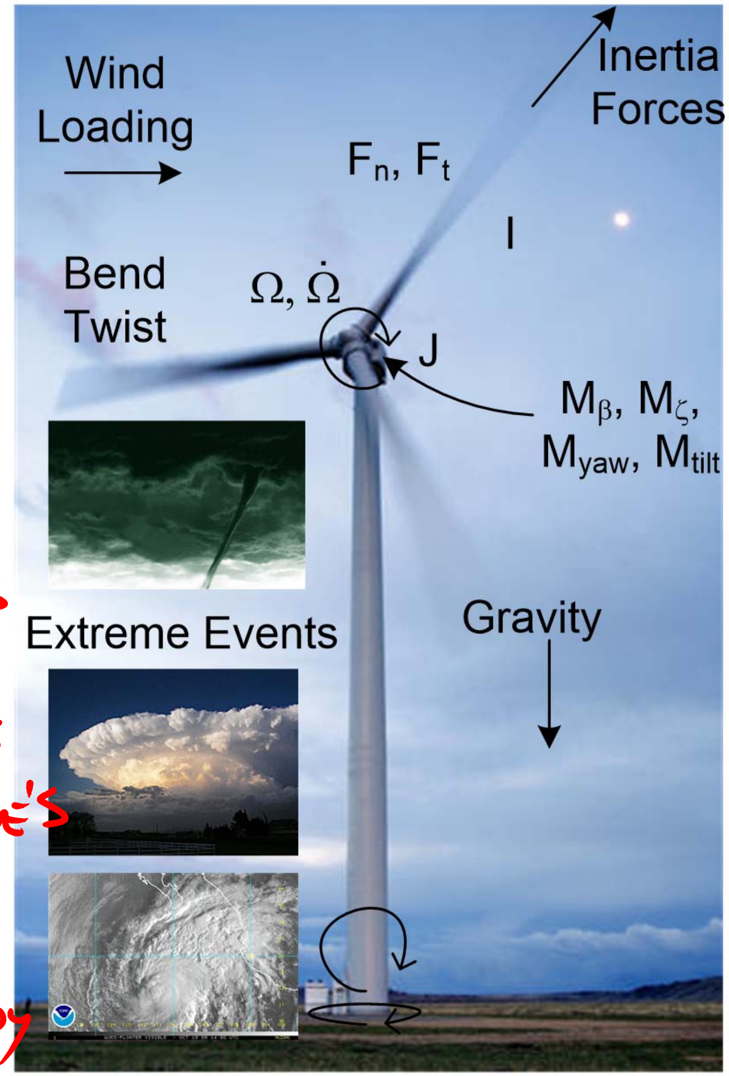
START BY BY DETERMINING LOADS

- DESIGN TURBINE TO WITHSTAND THOSE LOADS
- MODEL THE WIND TURBINE'S DYNAMICS

AS WIND PAST SUBJECTS

↳ LOADS ARE UNSTEADY

↳ FATIGUE WILL BE IMPORTANT

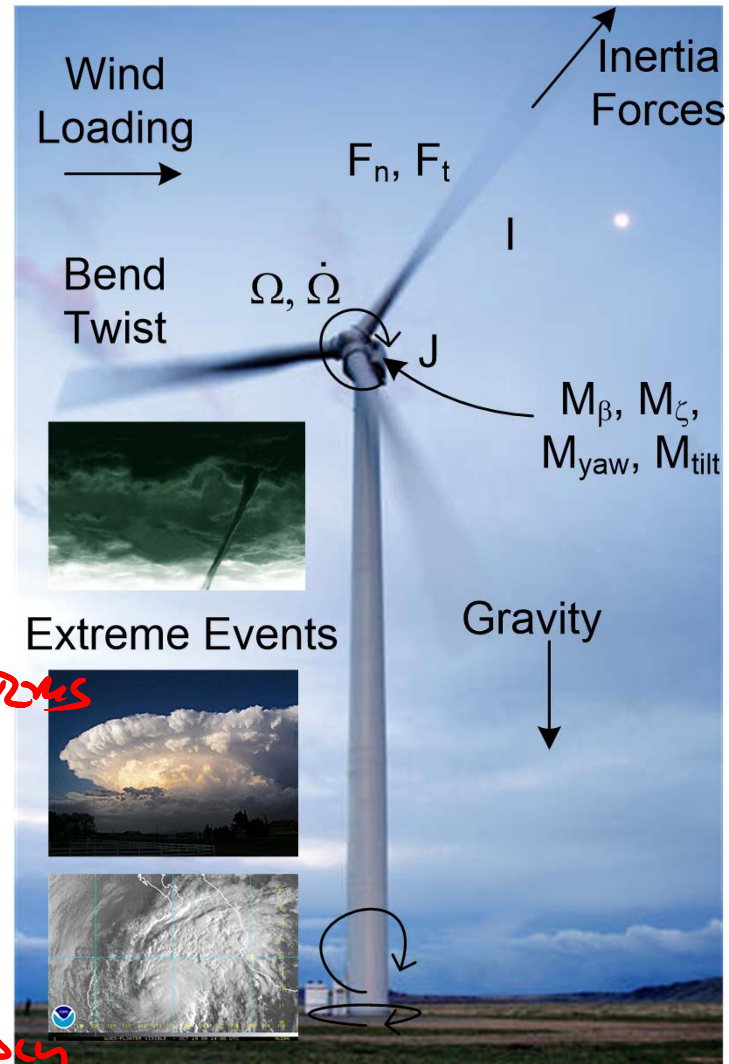


Wind Turbine Mechanics

A. Introduction

AREAS OF IMPORTANCE FOR WIND TURBINE MECHANICS

- BASIC MECHANICS
  - FORCES & MOMENTS
  - BEAMS
  - RIGID BODY ROTATION
  - GEARS
  - GYROSCOPIC MOTION
- VIBRATIONS
  - SINGLE & MULTIPLE DOF SYSTEMS
  - DAMPED, UNDERDAMPED & FORCED VIBRATION
  - ROTATIONAL VIBRATION
  - BEAM VIBRATION
- FATIGUE – INABILITY TO WITHSTAND LOADS APPLIED REPEATEDLY



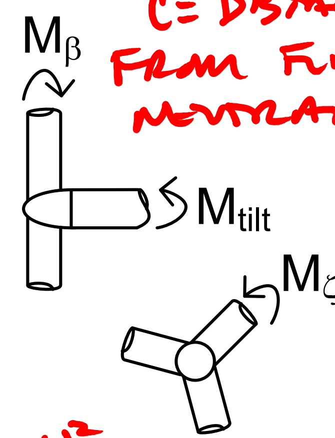
Wind Turbine Mechanics

I_b = AREA MOMENT OF INERTIA OF BLADE CROSS SECTION AT ROOT

$\perp$ TO ROTOR PLANE

B. Wind Turbine Loads

WANT TO UNDERSTAND KEY LOADS AND WHERE THEY ORIGINATE



C = DISTANCE FROM FLAPWISE NEUTRAL AXIS

1. Primary Loads

FORCES IN THE NORMAL DIRECTION

THRUST – PRIMARILY DUE TO AERODYNAMIC LOADING – F_n

$$T = \int_0^R F_N \, dr \qquad T = C_T \tfrac{1}{2}\rho U^2 \pi R^2$$

πR^2 → ROTOR AREA

U → UNDISTURBED WIND VELOCITY $U_{1,x}$

C_T → THRUST COEFFICIENT

THRUST LOADING TENDS TO BEND BLADES OUT OF THE ROTOR PLANE

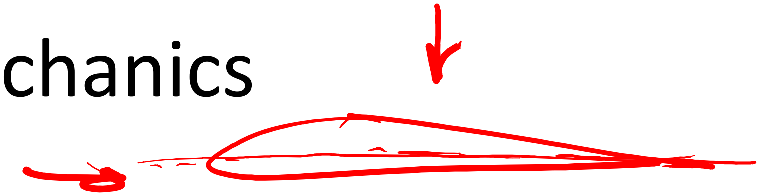
BENDING OFTEN CHARACTERIZED BY <u>FLAPWISE</u> BENDING MOMENT DEFINED NEAR THE BLADE ROOT $M_\beta = \int_0^R r F_n \, dr$

MAXIMUM FLAPWISE STRESS

$$\sigma_{\beta,max} = M_\beta c / I_b$$

BLADE SHEAR FORCE $S_\beta = \dfrac{T}{B}$

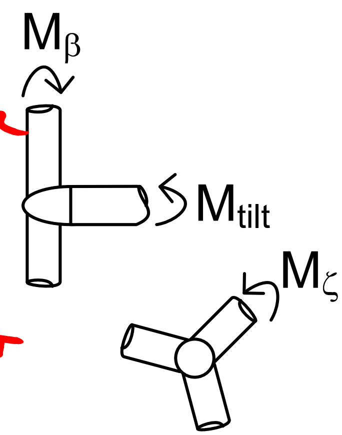
Wind Turbine Mechanics



B. Wind Turbine Loads

1. Primary Loads

FORCES IN TANGENTIAL DIRECTION



SEVERAL CONTRIBUTIONS TO THIS

TANGENTIAL AERODYNAMIC FORCES F_T

& TORQUE THEY PRODUCE

$$T_x = \int r F_T \, dr$$

MOMENT OF IMPORTANCE HERE IS CALLED THE EDGEWISE BENDING MOMENT (LEAD-LAG)

$M_y = T_x$ AT ROOT OR TOTAL TORQUE DIVIDED BY # OF BLADES

BLADE ROOT EDGEWISE SHEAR FORCE

$$S_y = \int_0^R F_T \, dr$$