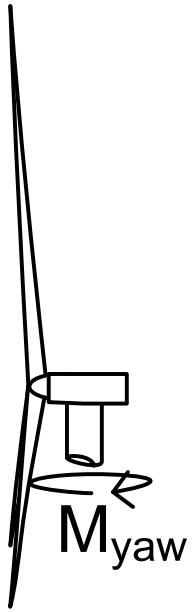
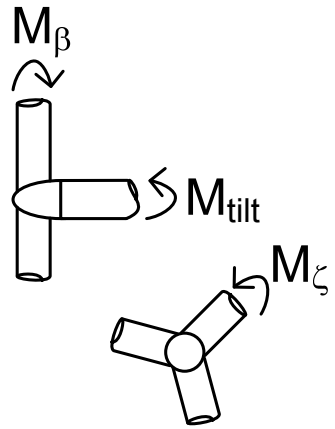
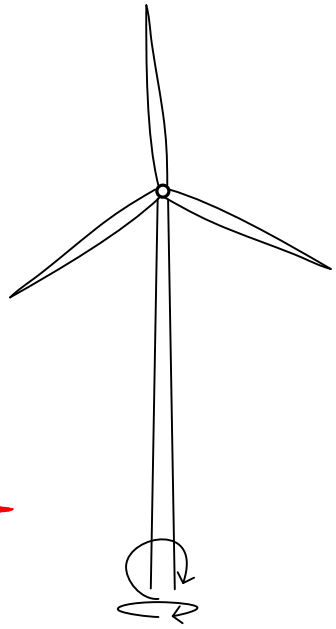
Wind Turbine Mechanics

B. Wind Turbine Loads

1. Primary Loads







OTHER IMPORTANT LOADS

M_{TILT} – MOMENT ON ROTOR SHAFT TRYING TO LIFT THE NACELLE OVER THE TOWER

M_{YAW} – MOMENT ON NACELLE TRYING TO TURN IT ON THE TOWER

TOWER MOMENTS

MOMENTS TRYING TO TIP OVER OR TWIST THE TOWER

Wind Turbine Mechanics

BLADE LOAD DUE TO GRAVITY VARIES CYCLICALLY AT ROTOR FREQUENCY

B. Wind Turbine Loads

2. Sources of Load

AERODYNAMIC LOADING, GRAVITATIONAL LOADING, INERTIAL LOADING

a. Gravitational Loads

GRAVITY CONTINUOUSLY LOADS THE BLADES
- DIRECTION VARIES

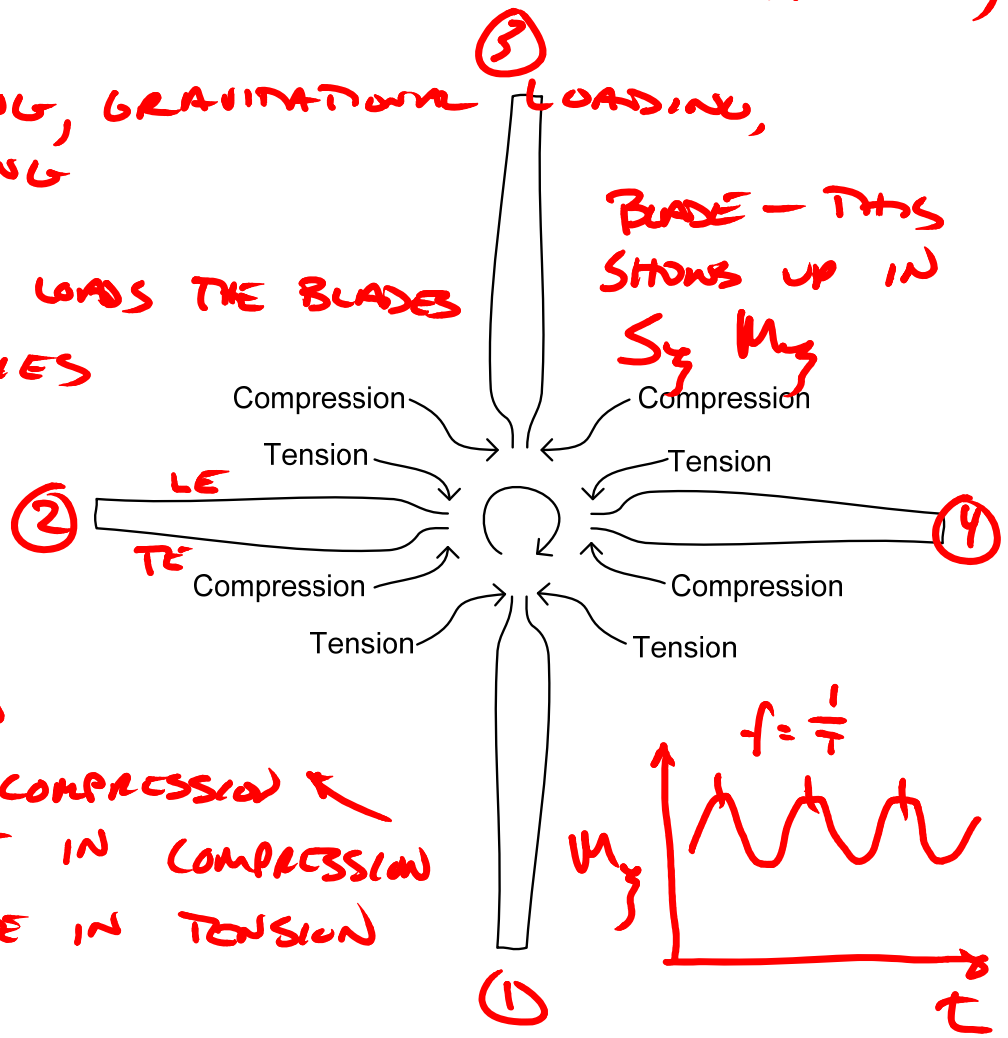
BLADE – THIS SHOWS UP IN S_y M_y

① BOTTOM – BLADE ROOT IN TENSION

② UPWARD – BLADE ROOT LE IN TENSION
BLADE ROOT TE IN COMPRESSION

③ TOP – BLADE ROOT IN COMPRESSION

④ DOWNWARD – BLADE ROOT LE IN COMPRESSION
BLADE ROOT TE IN TENSION



Wind Turbine Mechanics

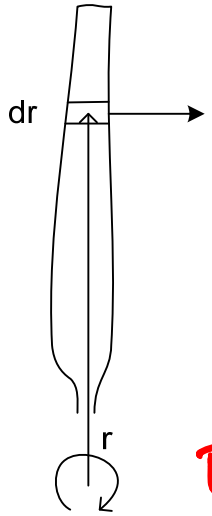
B. Wind Turbine Loads

2. Sources of Load

b. Inertial Loads

TWO INERTIAL LOADS TO CONSIDER

- CENTRIFUGAL FORCE
- ACCELERATION/DECELERATION



ACCEL/DECEL FORCE

MA PART OF EQUATION

$$dF_i = \dot{\Omega} r \, m \, dr$$

m = MASS/length

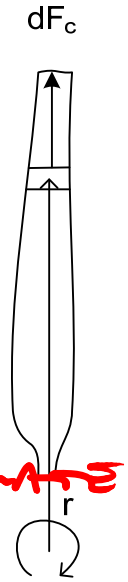
FORCE ONLY PRESENT WHEN ROTOR ACCELERATES/DECELERATES

CENTRIFUGAL FORCE

FORCE REQUIRED TO KEEP BLADES ROTATING IN A CIRCLE

$$dF_c = \Omega^2 r \, m \, dr$$

(Ω: a, m: m)



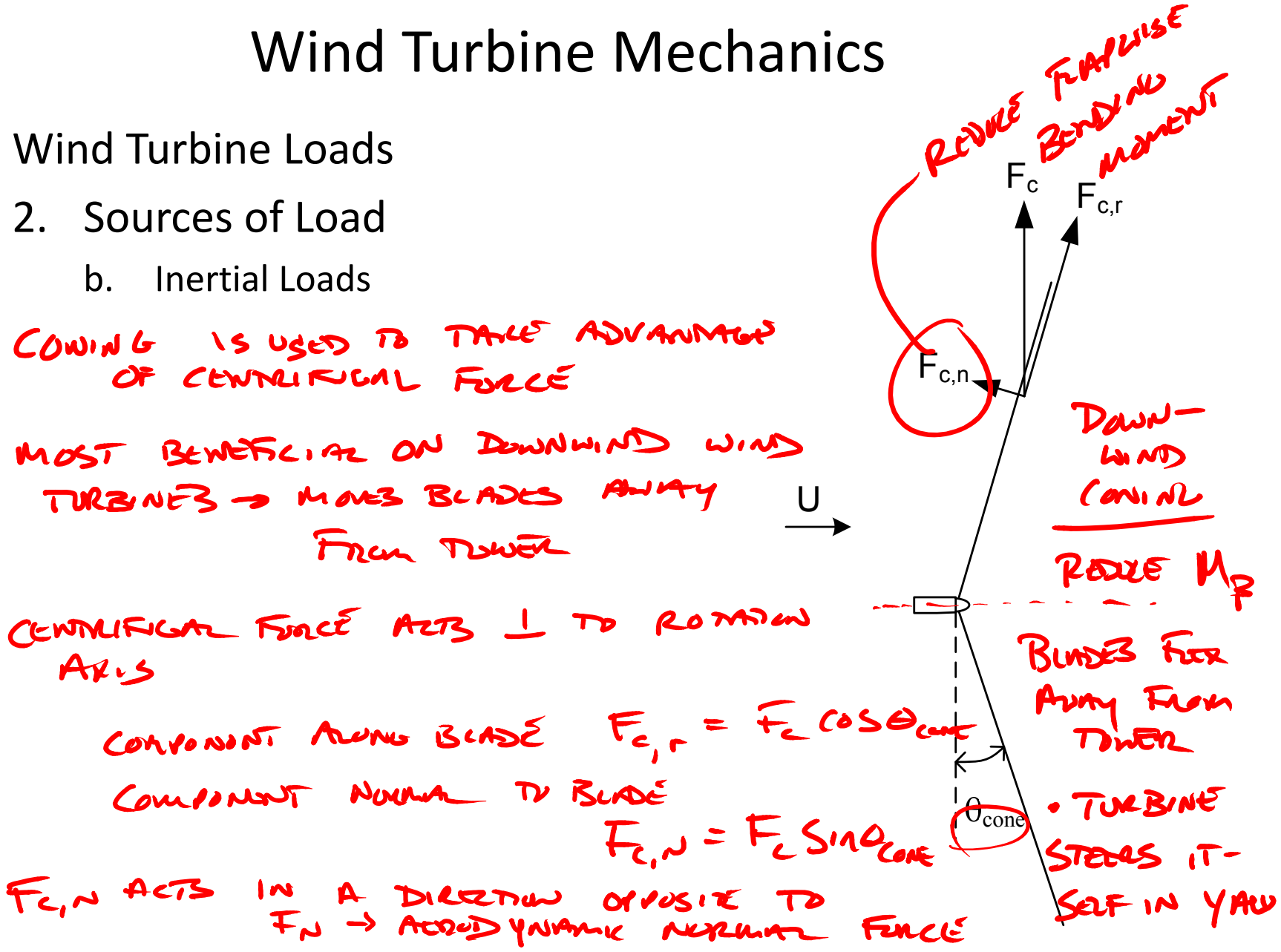
BLADE IS IN ROTATING COORDINATE SYSTEM

Wind Turbine Mechanics

B. Wind Turbine Loads

2. Sources of Load

b. Inertial Loads



Wind Turbine Mechanics

B. Wind Turbine Loads

2. Sources of Load

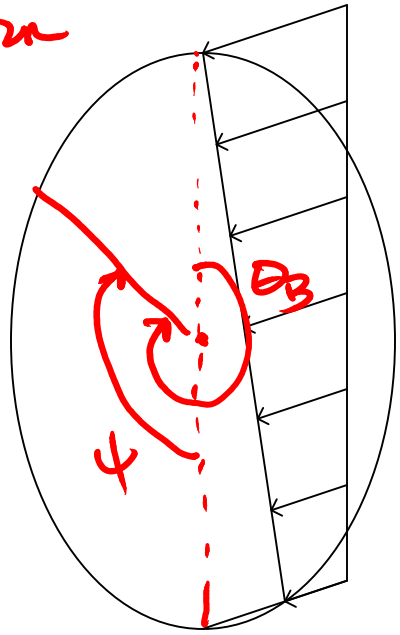
c. Aerodynamic Loading

CLASSIFY AERODYNAMIC LOADS

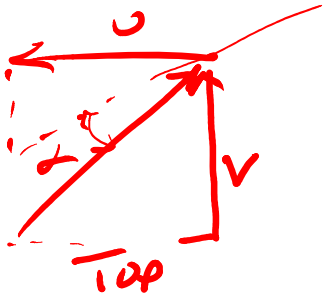
WIND = MEAN + SHEAR + TURBULENCE

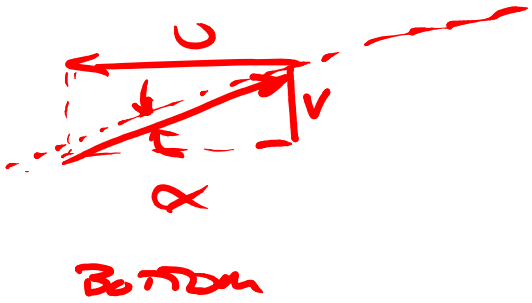
& THEN THOSE ARE EXTREME EVENTS

FREQUENCY IS THAT OF ROTOR



WIND SHEAR





BOTH α & W CHANGE AS A FUNCTION OF POSITION OF BLADE (ψ, θ_b)

α CHANGES C_L & C_D → C_N, C_T CHANGE

$F_N = C_N \frac{1}{2} \rho W^2 c$ ← W AFFECTS FORCES

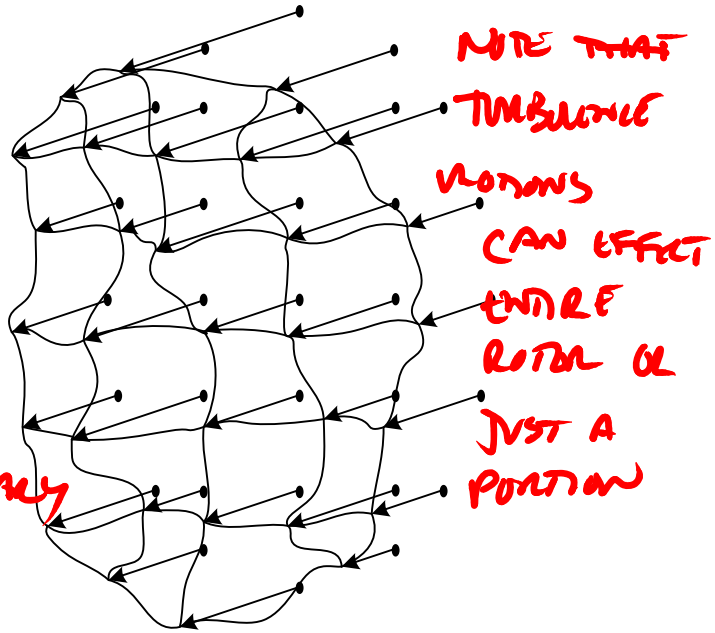
Wind Turbine Mechanics

B. Wind Turbine Loads

2. Sources of Load

c. Aerodynamic Loading

TURBULENCE IN WIND INFLOW
- PRODUCES VARYING LOADS AT FREQUENCIES AND LENGTH SCALES OF THE ATMOSPHERIC BOUNDARY LAYER



NOTE THAT TURBULENCE VARIATIONS CAN EFFECT ENTIRE ROTOR OR JUST A PORTION