Wind Energy

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Lecture 47: Mechanics: Wind turbine rotor dynamics

Continue our discussion on this wind turbine rotor dynamics so what we have discussed or completed so, far the basic principle from here the different types of loads and then how the loads impact the rotor dynamics so what we want to talk about is that the This wind turbine rotor dynamics how this impose loads and dynamic interaction produces forces and motions in wind turbines so that's what we are talking about this wind turbine rotor dynamics and these are important to understand this imposed load dynamic interaction which produces forces and motions and that is required for design process. Okay. So, the effects of all types of load, whether static, steady, cyclic, transient, impulsive, stochastic, that one has to determine. So, all types of loads need to be determined okay so what we are going to do here is that we are going to analyze the forces and motions which are to be considered so we start with a rigid rotor model and then we would develop the linearized system now So, the loads in an ideal rotor, loads in an ideal rotor, the most important rotor loads are with first on the legs and top drive the rotor. So, obviously when you try to model the rotor as a simple rigid aerodynamically ideal rotor to be useful to get a filling for steady loads on a wind turbine. So, the So, the primary thing is that, let's say, if you talk about thrust, which we have already estimated as Ct rho I R squared and U squared.

So, CTU would be thrust coefficient. Rho is the density of air. Okay. The radius of rotor.

And U, what do you call it? Free steam. Velocity. For. Ideal is. It is.

Eight by nine. So, obviously. In terms of this simple model. Then the total thrust.

So. In. In. terms of simple model, the total thrust on a given rotor varies only with the square of one speed. So, that's number one. Number two, we have bending moments.

Loads in an Ideal Rotor

→ most important rotor loads are associated with thrust on the blades. & torque to drive the rotor.

Thrust: $(T) = C_T \frac{1}{2} \rho \pi R^2 U^2$

C_T = thrust coefficient
ρ = desity of air
R = radius of rotor
U / U_d = free stream velocity

for ideal case, $C_T = 8/9$

In terms of simple model, then, the total thrust on a given rotor varies only with the square of wind speed.

and this is so the bending moments are or one can say the blade bending moment are usually as either tap wise or ease wise. So, when you talk about the tap wise bending moments that cause the blades to bend a point or downward okay and uh so this is something when the blade and in the movement due to this flapwise motion. And the other one could be edgewise bending moments. So, these are parallel axis and this give or producing torque. So, these are sometimes referred as Lead lack.

Lead lack. So, that means you can have this, I mean, we have already shown the flapwise moment. And for that also, if you have moments and then along with the rotation, that steepens. So, from simplified picture, we have kind of seen that. So, that is one thing, flap-wise moment.

Then you can have ease-wise moment, which is parallel to the rotor axis. That means this is the rotor axis. Then there would be parallel to that. So, that means moments are kind of like this. which is going to be kind of an, if you look at this view, then it is having a motion like that.

So, this can be referred as a lead lag. This also gives rise to some kind of an or producing torque. These are bending moments and this is that. Now, we have some kind of an axial forces and moments, okay? The flapwise bending moment the up wise bending moments or moment at the ideal blade of a turbine with multiple blades in by of the first course for blade and two third of radius. This let's consider consider the rotor as made up of a series of concentric annually of width dr.

Consider, the rotor as being made up of a series of concentric annuli of width 'dr'
The root flapwise bending moment on a single blade (M_β), for a turbine with B blades,

$$M_\beta = \frac{1}{B}\int_0^R r\left(\underbrace{\tfrac{1}{2}\rho\pi\tfrac{8}{9}U^2 2r\,dr}_{\equiv \text{ incremental normal force}}\right)$$

$$M_\beta = \frac{T}{B}\cdot\frac{2}{3}R \Leftarrow$$

β = angle of blade deflection in the flap direction

flap wise bending moment single blade let's say m beta for a turbine with d number of blades can be written as m beta one by B, zero to R, R, Y, eight by nine, use two R there. If we integrate this term and gather this, so upon integration and gathering terms, so, what we get, is that m beta equals to p by p to third r. So, this is the flap voice bending moment on a single blade. Okay, I mean, if you multiply by the beta, then total voice bending moment uh found out um so what we can estimate is that uh maximum flap y space so the maximum flap y space which is sigma beta max due to bending at the root which we can write as sigma beta max m beta into C area IB here C is the distance from the clockwise neutral axis IB is the area moment of inertia of blade cross-section at the root. This is how one can find out the maximum flapwise stage so, you can see this term here this is the same as incremental one force okay and here the beta normal force and subscript beta here and blade deflection angle blade deflection in the flap direction.

direction. Okay. So, this is used to emphasize the continuity between things that we are going to talk in the subsequent discussion. Now, like maximum flap wise test so the shear force A sub beta in the root of the blade so can be estimated like the thrust added with number of blades. So, what it talks is that if I have to summarize this moment then ideal rotor bending forces and stresses vary with the square of the wind speed and independent of blade angular motion or position which is azimuthal so the blades on rotors designed for higher tip speed ratio operation smaller cords and cross-sectional area moment of inertia so they experience higher flap voices so this is what one can so essentially in summary one can say for a given ideal rotor bending forces and stresses Very. With U square.

the max. flapwise stress ($\sigma_{\beta,max}$), due to bending at the root:

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

(c = distance from the flapwise neutral axis
I_b = area moment of inertia of blade cross section at the root)

The shear force (S_β), in the root of the blade $= T/B$

And. Of. Glade. Angular. Position. Also. Blades on rotors speed ratio operation have smaller cross-sectional area moment of, inertia. So, the, experience, .

Okay? So, that's what happens, with, Flapwise bending moments. Now, we can similarly edgewise forces and moments can be estimated. So, as already mentioned, that is wise moments give rise to the or producing torque. So, in terms of blitz and aerodynamic is wise moments are generally of less significance than their clap voice contact points. So, mostly the flapwise motions or the forces for that stasis or the moments that are created, they are quite predominant in that than edgewise motion.

But one thing one has to take into consideration that during operation for certain I mean for sometimes or it may possibly happen is that the this is when motions or the moments due to blades own weight can be significant and may have significant impact on the overall forces or moments that acting on that turbine. So, this is something we also need to look at it, that how one would estimate this age wise forces and moments and things like that. That will continue in the next session.