Wind Turbine Aerodynamics

NOTE:

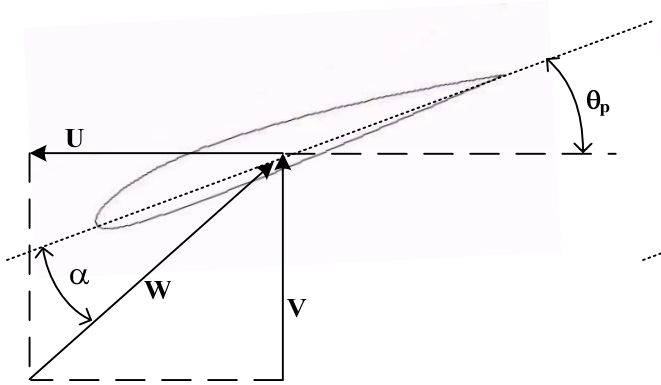
D. Blade Aerodynamics

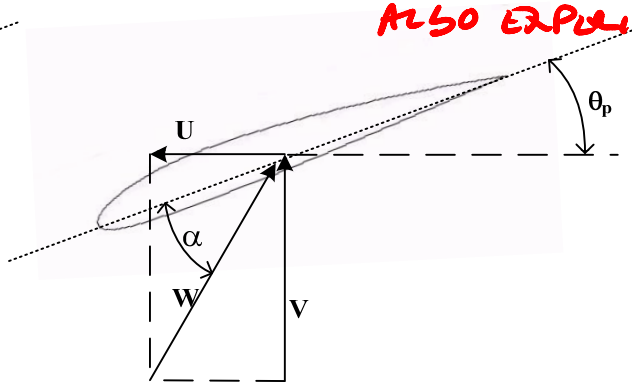
4. Various Effects on Angle of Attack

b. Variations in Rotational Velocity

ALL TURBINE BLADES EXPERIENCE AN INCREASE IN U WITH r

VARIABLE SPEED TURBINES ALSO EXPERIENCE VARYING U THROUGH Ω VARIATION





INCREASE / DECREASE } IN U YIELDS { DECREASE / INCREASE } IN α

BLADE ROTATION SPEED INCREASE $U = \Omega r$

INCREASE Ω

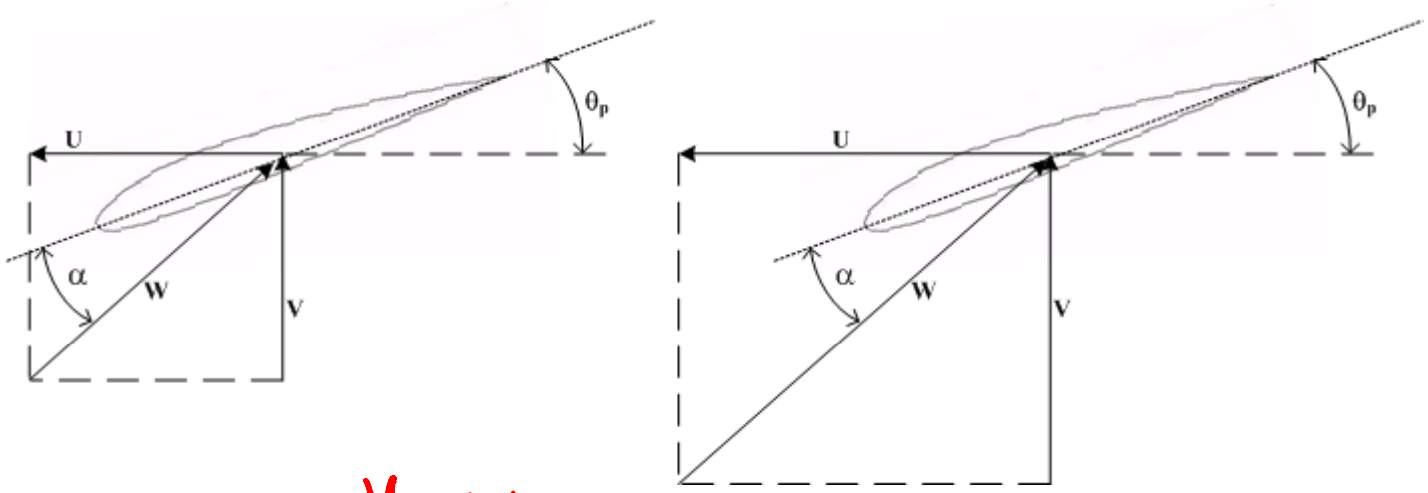
INCREASE IN r

Wind Turbine Aerodynamics

D. Blade Aerodynamics

5. Design Features to Overcome Varying α

a. Vary Rotation Speed to Overcome Variations in Wind Speed



INCREASED V INCREASES α } USE TOGETHER

INCREASED U DECREASES α }

PRIMARY MEANS OF MAINTAINING α IN SMALL TURBINES

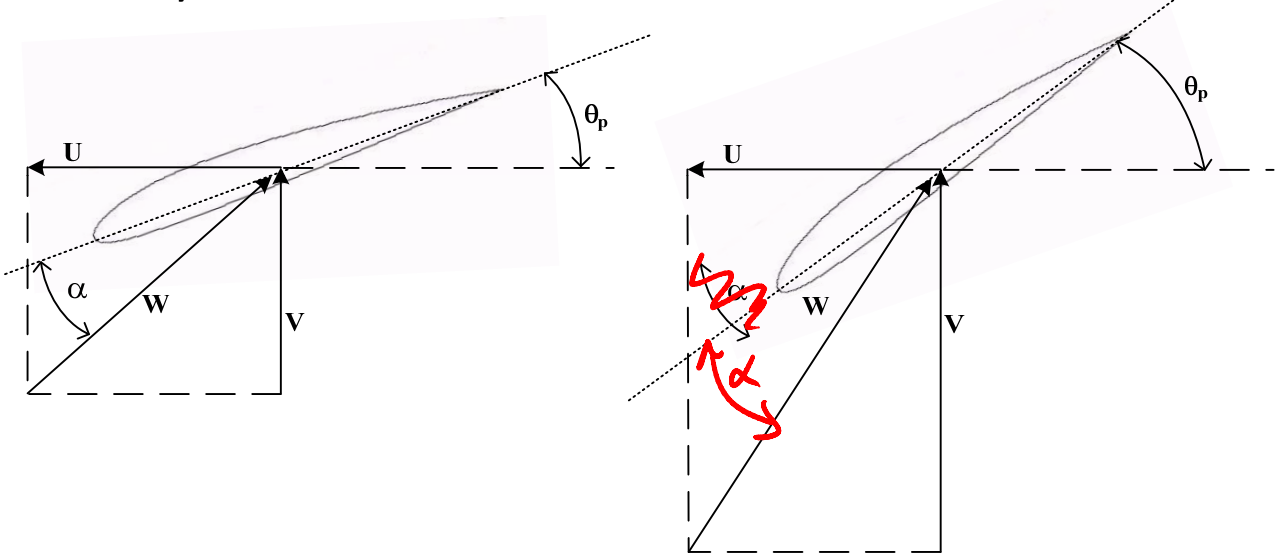
MODERN TURBINES USE VARIABLE SPEED FOR LARGE TURBINES

Wind Turbine Aerodynamics

D. Blade Aerodynamics

5. Design Features to Overcome Varying α

b. Vary Pitch to Overcome Variations in Wind Sp



WE FOUND THAT V INCREASES α

WE CAN MODIFY θ_p TO KEEP α CONSTANT

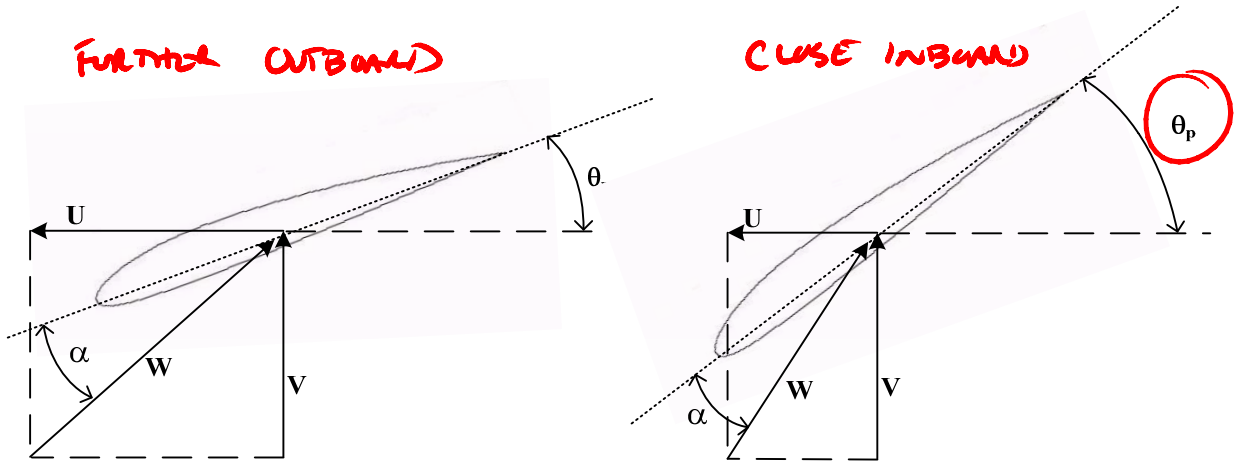
THIS IS THE PRIMARY WAY THAT MODERN TURBINES WORK

Wind Turbine Aerodynamics

D. Blade Aerodynamics

5. Design Features to Overcome Varying α

c. Vary Pitch to Overcome Variations in Rotation Rate



WE FOUND THAT DECREASE OF U INCREASED α FOR FIXED θp

WE MODIFY θp TO KEEP α CONSTANT

ALL WIND TURBINES HAVE U INCREASING WITH RADIUS

THIS IS WHY BLADES "TWIST" – θp DECREASES WITH r

Wind Turbine Aerodynamics

D. Blade Aerodynamics

4. ~~Effects of Blade Rotation~~

5. DESIGN FEATURES

BLADE TWIST IS EVIDENT IN ALL MODERN WIND TURBINE BLADES

GE 1.5 MW BLADES AT NREL (NWTC)

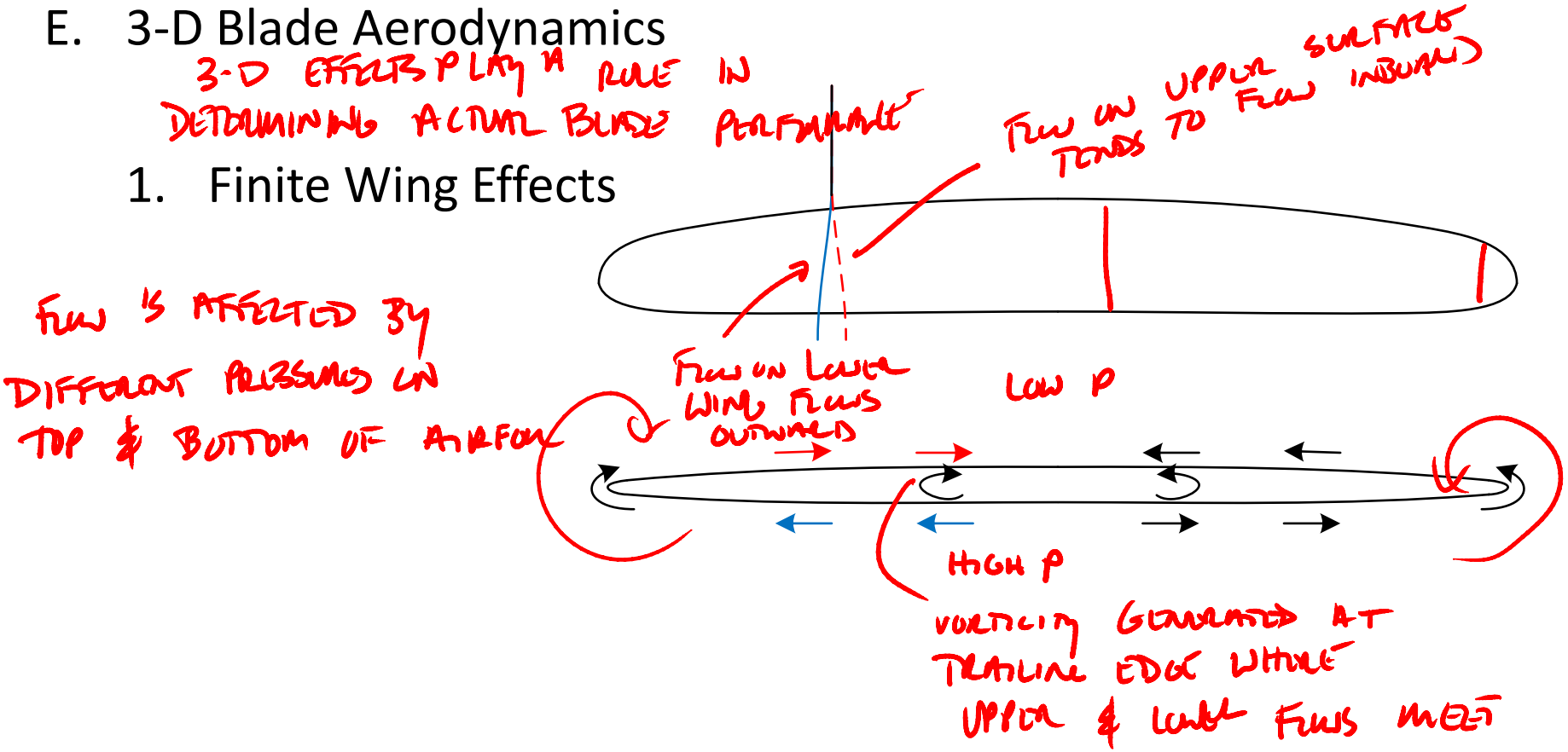
1.5 MW TURBINE NEAR AHLHORN, GERMANY

Wind Turbine Aerodynamics

E. 3-D Blade Aerodynamics

3-D EFFECTS PLAY A ROLE IN DETERMINING ACTUAL BLADE PERFORMANCE

1. Finite Wing Effects



TRAILING VORTICES

IF WE THINK OF THIS AS A SERIES OF DISCRETE VORTICES → VORTEX SHEETS OPPOSITE SENSE ON OPPOSITE SIDES