ABSTRACT

GENERATED BY HORIZONTAL AXIS WIND TURBINES ARE HIGHLY COMPLEX DUE TO THE SIMULTANEOUS PRESENCE AND INTERACTION OF THREE-DIMENSIONALITY, UNSTEADINESS, SEPARATION/REATTACHMENT AND ROTATIONAL INFLUENCES. BOTH PREVIOUS THEORETICAL COMPUTATIONS AND EXPERIMENTS ESTABLISHED THAT STALL-DELAY ROUTINELY OCCURS ON ROTOR BLADES PRODUCING BENEFICIAL VORTEX STRUCTURES RESPONSIBLE FOR SIGNIFICANT FORCE AND MOMENT AMPLIFICATIONS. A THEORETICAL ANALYSIS WAS PERFORMED BY BANKS AND GAAD FOR STEADY LAMINAR BOUNDARY LAYERS (BL) ON A ROTATING BLADE USING AN INTEGRAL METHOD AND AN EXTERNAL FLOW WITH A LINEAR ADVERSE VELOCITY GRADIENT. THEY CONCLUDED THAT ROTATIONAL EFFECTS COULD DELAY THE SEPARATION, AND AT EXTREME INBOARD STATION COULD STABILIZE COMPLETELY THE BL AGAINST SEPARATION. MORE RECENT, IN A TEHNICAL NOTE DUMITRESCU AND CARDOS USING A DIFFERENTIAL BL FORMULATION WITH THE SAME LINEARLY RETARDED EXTERNAL FLOW, FOUND SIMILAR RESULTS AND THE CORIOLIS FORCES OCCURING IN THE SEPARATED FLOW WERE POSTULATED AS MAIN CAUSE FOR STALL-DELAY AND INCREASED 3D POSTALL LIFT COEFFICIENT. LACK OF INFORMATION ABOUT THE BL CHARACTERISTICS OF ROTATING BLADE AFTER SEPARATION PROMPTED THIS INVESTIGATION. SNEL'S MODEL GAVE THE FIRST ESTIMATE OF 3D EFFECTS IN STALL, WHICH HAVE BEEN VALUABLE FOR UNDERSTANDING OF ROTOR BEHAVIOUR. THE REASON FOR AN ALTERNATIVE MODEL WAS TO INCLUDE THE OFTEN OBSERVED AND INTUITIVELY EXPECTED RADIAL FLOW, WHICH IS NOT DOMINANT IN SNEL'S MODEL. OUR MODEL ALSO BASED ON BL THEORY IS VALID IN THE SEPARATED FLOW AND SHOWS THAT THE SEPARATED FLOWS ARE DOMINATED BY THE CORIOLIS FORCE AND RADIAL DERIVATIVE TERMS. THE MODEL DESCRIBES THE SEPARATED FLOW ON ROTATING BLADES ASSUMING A HYPOTHETICAL ZERO SKIN-FRICTION FLOW FOR THE INVISCID EXTERNAL FLOW. HOWEVER, BY STUDYING THE EFFECTS OF THE VARIOUS SECONDARY TERMS ON THE PRIMARY FLOW OVER THE ROTOR BLADE IT PROVIDES VALUABLE INSIGHTS FOR A THEORETICAL UNDERSTANDING OF THE PHYSICS OF FLOW SEPARATION.