STRESS ANALYSIS OF A TURBINE BLADE WITH LAYERED COMPOSITE MATERIAL BY FINITE ELEMENT METHOD

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Abstract : *The turbine blades are used for extracting energy from high temperature and high pressure gas produced by a combustor. Turbine blades of wind turbine and water turbine are designed to work at various operating conditions involving rotational speeds, temperature and pressures. During this process, stresses are generated and needs to be estimated for eliminating the failure. Thus, the present work aims to find out the deflections and stresses in a turbine blade with layered composite material. The blade is subjected to loading condition of internal pressure and commercial software ANSYS is used for simulation purpose.*

Keywords: layered composite materials, turbine blades, shell structures, stresses and deflections

1. INTRODUCTION

The design of a turbine blade is a complex process that involves the know-how of materials, modeling, simulation and various testing methods. The design process involves the knowledge of external loads due to wind pressure and gravitational influences. It also involves an understanding of material behavior and failure analysis at various length scales. Further, the structural design also involves minimizing cost and weight of a turbine blade subjected to various constraints. Finite element analysis of a turbine blade helps a designer to represents the structure with accurate geometry and material properties for actual physical testing. The cost of preparing the number of actual prototypes is also reduced. Thus, Finite element method forms the basis for various design problems in science and engineering. The modern turbine blades consist of varying composite materials layups throughout the structure that are subjected to various aerodynamic loading cases with pressure distributions. The deflections due to the external loads can be effectively simulated by finite element analysis software ANSYS.

Even though loading approximations is a common practice in wind turbine blade design, but very little work has been published on finite element analysis of a turbine blade with layered materials. Finite element analysis software ANSYS was used to analyze the composite wind turbine blade subjected to largest combined loads to find the stresses [1]. A wind turbine blade subjected to structural loads applied via a rigid link was analyzed and the stress results were compared [2]. A computer program package was developed for the multi-criteria optimum design of wind turbine blades [3]. An innovative method for structural optimization of laminated composite shell Structure a wind turbine blade has been presented for maximum stiffness or lowest Eigen frequency [4]. A detailed optimization procedure was presented for a horizontal axis wind turbine blade based on ultimate limit state analysis where laminate layer thickness, material type and orientation angle are tailored for the structural performance that are subjected to three design constraints[5]. Thus, keeping on the impetus on the design of a turbine blade, present work on stress analysis of a turbine blade with layered composite material has been carried.

2.0 FINITE ELEMENT ANALYSIS:

General purpose software ANSYS has been used for modeling and simulation of the shell structure. 3D 4 node 181 element is used for modeling purpose. Material properties are assumed to be linear and elastic with an Young's modulus of 190 x 10^9 Pa and a Poisson's ratio of 0.25. The material is assumed be homogeneous. Static structural analysis has been carried for defection and stresses.

The shell structure is assumed to be with five layers of thicknesses 0.1, 0.05, 0.05, 0.05 and 0.1 respectively. The orientation of the layers is 0º, 45º, 90º, -45º and 0º. The shell structure with layers and orientation is as shown in figure in figure-1. A cylinder is created with outer radius of one unit with z1, z2 dimensions of 0, and 8 units and with an ending angle of 90º. The volume created to obtained thin sectioned blades is shown in figure-2. The blade structure with finite element mesh is shown in figure-3. The detailed mesh of the magnified model with various layers is shown in figure-4.

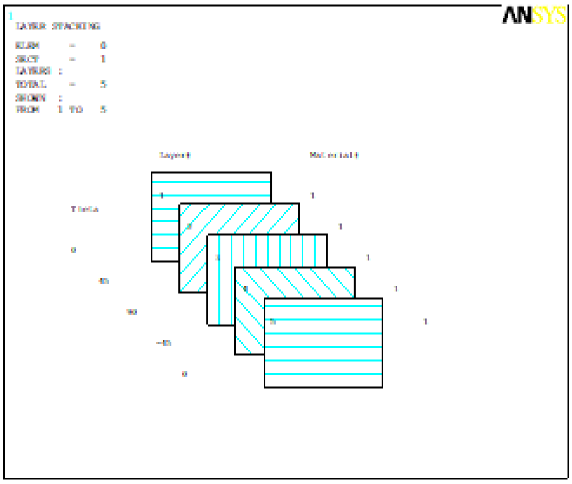

Figure-1: lay up of shell structure

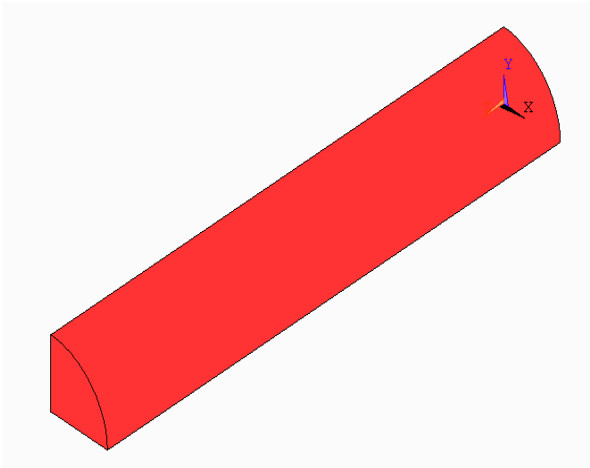

Figure-2: Volume of shell structure

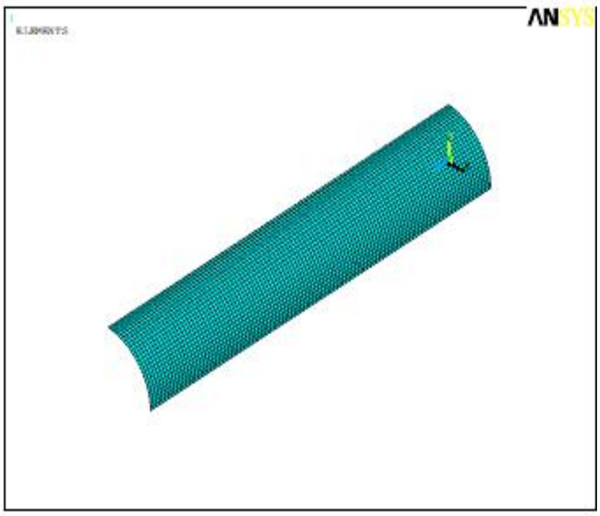

Figure-3: Mesh of the blade

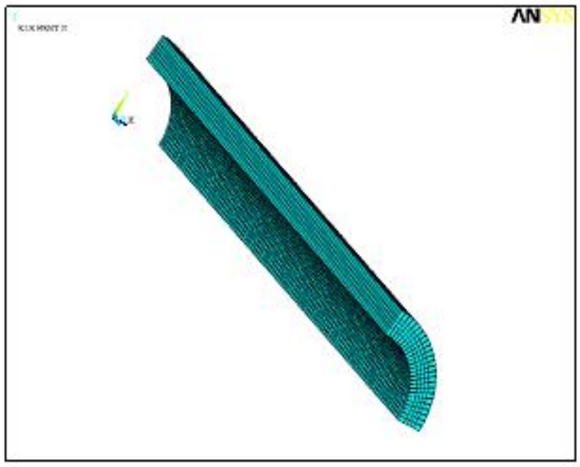

Figure-4: Mesh of the magnified model with layers

3.0 RESULTS AND DISCUSSIONS:

Structural pressure load of 5e7 Pa is applied on the right end of the blade. The deflections and stresses are found and simulated. The loading and boundary conditions are shown in figure-5. The deflection of the model is shown in figure-6. The full length of the model is the model before applying the load dark colored thick area indicates the deflected model. A deflection of about 0.0006m is found toward the right end of the blade. The nodal solution of displacement is shown in figure-7. The von mises stresses and strains are shown in figures-8 and 9 respectively. The stresses are more concentrated near the fixed end.

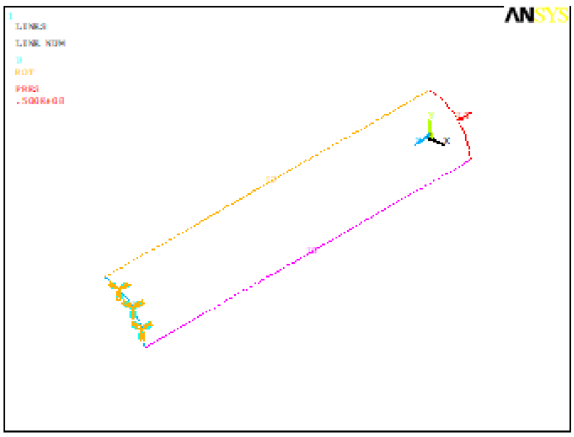

Figure-5: Loading and boundary conditions

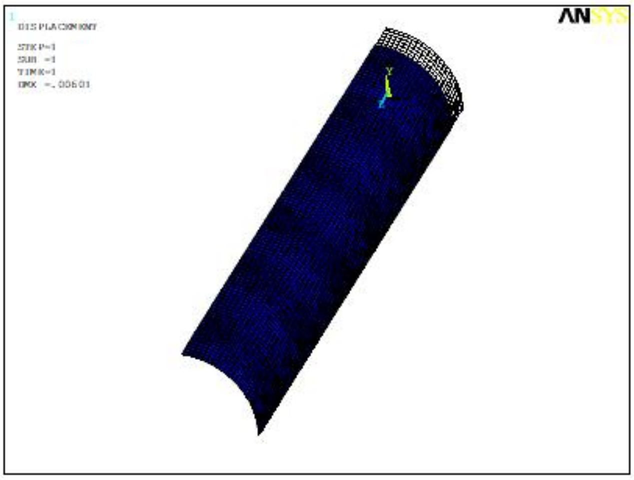

Figure-6: Deformed shape.

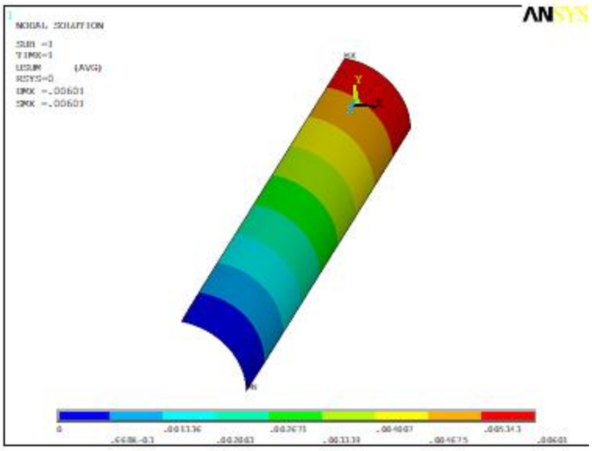

Figure-7: The nodal solution of displacement.

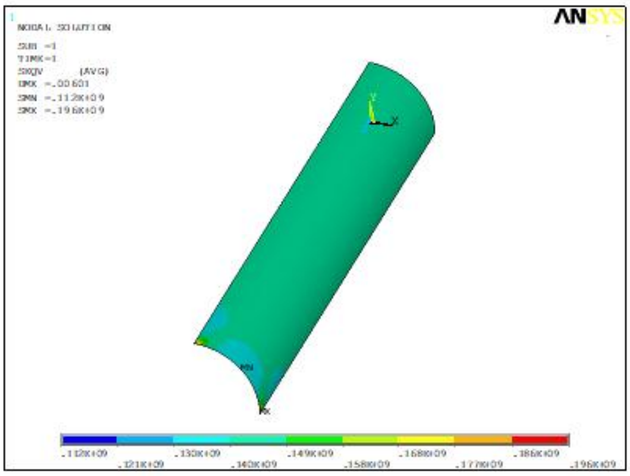

Figure-8: von mises stresses.

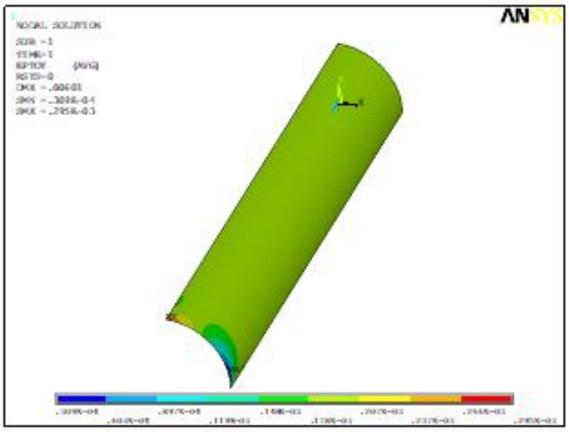

Figure-9: mechanical strain y-direction

4.0 CONCLUSION: A turbine blade with layered materials has been modeled and simulated for stresses and deflections due to a pressure load. A shell structure of lay up of five layers with variable thickness and orientation has been modeled. ANSYS software has been successfully implemented in finding the deflection and stresses. It is found that the stresses are more concentrated near the fixed end support.

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