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Using of Composite Material in Wind Turbine Blades

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Abstract: The turbines manufactured from the mid 1980s until the late 1990s were mainly constructed using standard components. After that period, special components started being designed and manufactured for turbine use only. One of the best solutions is using composite materials in wind turbine. Most composites are made up of just two materials. One material (the matrix or binder) binds together a cluster of fibers or the fragments of a much stronger material and the second material (the reinforcement) surrounds these fibers or fragment. Nowadays, many wind turbine manufacturers are taking a big interest in composite materials which many researcher of wind technology see as the materials of the future. The main concern is to get the cost down, so that composites can be used in products and applications which at the present time don't justify the cost. At the same time they want to improve the performance of the composite, such as making them more resistant to impact. In this article the using of composite material in wind turbine blades were investigated. The research was based on the theories material science and wind technology. And also some practical results were exhibited and explained.

Key words: Wind turbine, blade material, composite materials, fibre technology

INTRODUCTION

Rapid advancements in material technology have created some variations in the structure of wind turbines. That variation primarily provided positive impacts for lowering the prices of wind turbines. As it is known, in wind turbine structures wide range of materials are used. However, many factors such as mechanical equipment, fatigue resistance, corrosion resistance, breaking toughness, rigidity, weight and appearance have impacts on wind turbine materials. That fact recently has caused materials such as composite to be used widely in wind structures.

In wind structures, blades are certainly influential component for system efficiency. Dimensions and numbers of that component vary on the basis of turbine strength its development in past related to its materials used in its design varied from cloth to wood and sheet metal but, in last years composite material has been implemented by all turbine manufacturers (Eker and Vardar, 2005).

On the other hand, that significantly important component for wind turbines must be known very well related to design parameters (Fig. 1).

A section of a blade at radius r is illustrated in Fig. 2, with the associated velocities, forces and angles shown. The relative wind vector at radius r, denoted by W, is the resultant of an axial component u P and a rotational component u T. The rotational component is the sum of the velocity due to the blades motion, r Ω and the swirl velocity of the air, r ά Ω. The axial velocity u P, is reduced by a component Va 0, due to the wake effect or retardation imposed by the blades, where V_0 is the upstream undisturbed wind speed. The ά and ά terms represent the rotational and axial interference factors, respectively. The

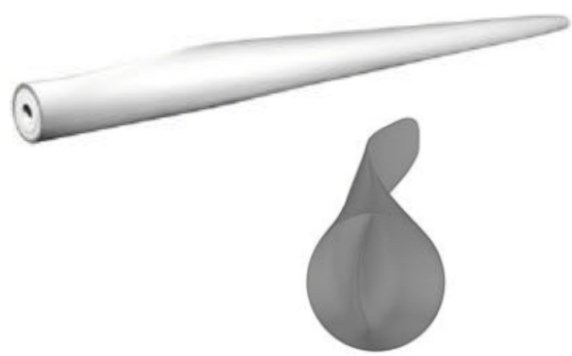

Fig. 1: Blade profile

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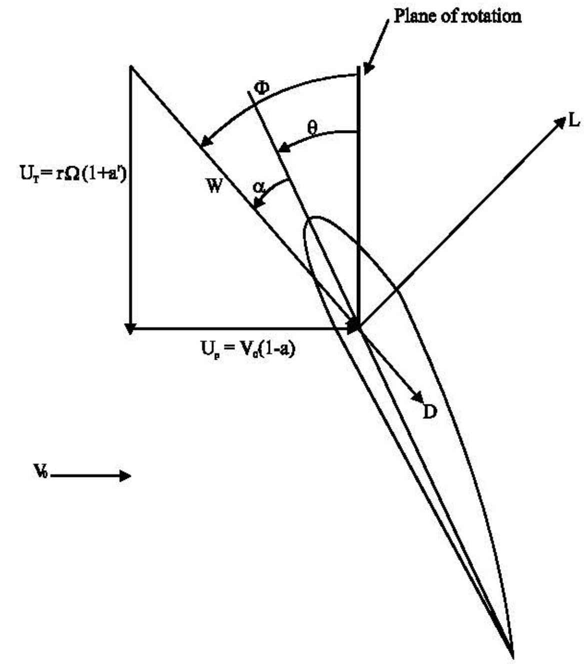

Fig. 2: Blade element force velocity diagram (Lee and Flay, 1999)

angle of attack is denoted by a, the pitch of the blade by q and the angle of the relative wind to the plane of rotation, by f. The resultant lift and drag forces are represented by L and D and directed perpendicular and parallel to the relative wind as shown (Lee and Flay, 1999).

A major problem influencing the design and operation of wind turbines is fatigue. The lifetimes of most components are gradually reduced by the high number of revolutions that occur at relatively low stress magnitudes. Turbine blades are the components which exhibit the largest proportion of fatigue failure (50%) and the centrifugal and gravity loads are primarily responsible (Eggleston and Stoddard, 1987). Other contributions to fatigue damage arise from, wind shear, turbulence, tower shadow and interference from upwind turbines. The affect that each of these factors has on the rotor is difficult to determine and much research is being conducted to gain an improved understanding, such as the work described by Noda (1997).

Considering all those factors, in that instructional study, implementation of composite materials in wind blades has been selected for explanation.

COMPOSITE MATERIALS

Generally, composite materials are constituted of metallic, organic or inorganic base structural components.

Fig. 3: A blade that is upright and away from the shadowing effects of the tower is exposed to quite different loads from a blade that is pointing downwards

Those are known as matrix, fibers, particulates, stamps, layers. Those structural components have limited geometrical shapes.

Actual functions of matrix as a volume component is to generate dispersion of other structural components such as fibers, particulates, stamp in its own structure, to provide a phase impact among those components. Also to transmit tensions arriving to material to reinforcing phase and to provide formation of composite material by means of convenient technical applications. In addition to that, imposing effects for physical, mechanical and chemical properties plays a major role as a determining factor for the formation of composite structure.

Components present in composite materials are solved inside each other, they have inert action chemically. However, especially, in metallic systems even in low amounts, a little magnitude dissolution and interfacial reactions influencing composite properties among components may be found.

Purpose of composite materials design on wind turbine blades may be tended for the sophistication of one or some of the physical, mechanical or chemical properties. For that purpose, different methods are used. Main principle certain in all of them is developing weak qualities of components in the course of main purpose for the achievement of more effective turbine blade (Fig. 3).

One of the main purposes for the composites used in turbine blades is to drop material fatigue to possible minimum level. Because, fatigue emerge in composite material is various compare to other materials. Crack on turbine blade exposed to altering loading in isotropic materials improve with diagnostic progressive change and blade undergoes a deformation at the end of period available to calculate (Vardar and Eker, 2004).

Since notch sensibility delays notch to pass toward fibre is lower in composite materials than metallic materials. Fatigue development in composites occurs in various forms depending on material. Fatigue emerging due to fibre-matrix interfacial surface bond power is defined as the fatigue encountered when load direction and fibre direction are varied. If crack progress along fibre damage is created. As long as fibre load direction remains same high level fatigue resistance is provided. In such a case, as fatigue resistance goes up with increasing volume rate. Fatigue in cross-sectional formation disperses originating from the layer where high tension is imposed according to its strength.

Since matrix materials are the part of composite exposed to environmental factors such as humidity, heat and chemical materials corrosion resistance determines its effects pertaining to environmental effects such as humidity, absorption.

COMPOSITES USED ON TURBINE BLADES

The modern wind turbine, sometimes called the rotor, usually consists of two or three blades made of high density wood, plexiglass or composite material. Designed like an airplane blade, these blades develop an imbalance between the lift and drag forces to capture the wind's energy. According to Bernoulli's principle, a pocket of low pressure forms on the leeward edge of the moving blade as it passes through the wind. This pressure pulls the blade, causing the turbine to rotate against the counter-torque induced by the drag force, the generator and by system losses. This modern airfoil design captures the wind's energy much more efficiently than old farm windmills that rely on the force of the wind pushing against the blades.

Turbine aerodynamics (including shape and blade count), material composition and size are fundamental issues in wind power system design. The rotors of modern wind turbines generally consist of three blades, with their speed and power controlled by either stall or pitch regulation. Stall regulation involves controlling the mechanical rotation of the blades; pitch regulation (now more commonly used) involves changing the angle of the blades themselves. Rotor blades are manufactured from composite materials using fibreglass and polyester or fibreglass and epoxy, sometimes in combination with wood and carbon.

The most commonly used types of composite material in the wind turbine industry are glass fibre-reinforced plastics (GRP). GRP dominates the market because it provides the necessary properties at a low cost. The important characteristics of GRP are good mechanical properties, good corrosion resistance, high temperature tolerance, ease of manufacture and favourable cost. More importantly, composite materials enable structures to be designed to provide significant advantages such as weight reduction, over traditional engineering materials, whilst maintaining the required levels of performance and reliability.

GRP designed during the end of 1940's is most widely used and initial modern polymer based composite material. Presently, approximately 85% of all manufactured composite materials are GRP (Dorey, 1988).

Physical shapes of fibers are significant factor for new material's properties. Reinforcements are basically present in three different forms as particles, discontinuous and continuous fibers. Although generally particles are in a spherical shape approximately they are equal dimensions in every direction. Discontinuous fibers (shredded fibers, grinded fibers or whiskers-fringe) may be in the range of few millimeters to few centimeters. Diameter of most fibers doesn't exceed few micrometers. Thus, very long length is not necessary for the conversion of fibre from a particle form to fibre form.

Continuous fibers are used in a rope shape without cutting in some methods like wire wrapping. Highest mechanical properties of fibers are seen on their length rather than their width. Those properties cause composite materials to manifest their excessive anisotropic functions which are not seen on metals. Thus, it is very important to consider fibers locations in rosin and their geometry at turbine blade design stage. Anisotropic property of material is available to provide gains by using in convenient place of product at design stage. In some cases, for reinforcing material's resistance fibers are used as cloth for providing equal strength in every direction. Textile fibre cloths prepared in continuous fibers possess various types developed for different purposes.

Although glass fibre is the most commonly used and reinforcing material presently in sophisticated composite materials usually pure carbon fibre is used (Mallik, 1990). Although carbon fibre is stronger and lighter than glass fibre its manufacturing cost is higher. Stronger and more expensive one than carbon fibre is the boron fibre. Polymers apart from their usage as matrix fibre they are also used for manufacturing fibers for composites. Aramid is a polymer fibre which provides much higher strength and rigidity to composite material. Aramid is used in products in which light and confidential construction is aimed for composite materials.

Fig. 4: Glass fibre

Glass fibre is manufactured from glass manufacturing materials such as silicate, colemanit, aluminum oxide, soda (Fig. 4). Glass fibre is most commonly known and used one among fibre contributed composites. Glass fibre is manufactured by pushing melted glass produced from a specially designed furnace which holds small holes at the base. On wind turbine blades E-Glass and S+R Glass types are used.

E-Glass is the most commonly used glass type in the manufacturing of Reinforced fibers. It has low cost, effective insulation and low water absorption rate properties. S+R Glass is a material possessing low cost and high performance properties. Diameters of wires in fibre is equal to half of the E Glass, therefore, numbers of fibers increase so tougher surface quality is provided which refers to stronger combination quality. Depending on the purpose of glass fibre use fibre wrapping types may differ.

Fibre diameter and fibre numbers in the bulk may be different. After glass fibre shape is provided, with the aim of providing resistance to deformation sealing process may be implemented by chemicals. As sealing material usually, polymers which dissolve in water and available for easy elevation are used before the implementation of fibers to composite material. Attachment between fibre and resin is very important. Due to lack of high quality attachment separation between additional material and matrix reduce the rigidity and long-lasting property of composite material. For preventing that factor, fibre is coated by chemicals.

IMPACT OF WIND STRIKE ON COMPOSITE MATERIAL

In wind turbine technology for preventing unexpected outcomes caused by a wind strike originated from external environment material is expected to provide most convenient respond or reaction. Based on the intended use and place where application is generated possible strikes imposing on material may arouse in plenty of different ways. Against that, respond given to strike is determined by material.

Composite materials have properties capable to drop the strike into minimum level. Respond for strike although can be in the form of a rupture at the end of changing plastic shape, composites may undergo injuries in plenty of various modes and in those injury modes no significant alteration emerge in dimensional integrity of material. Usually invisible and very weak magnitude injuries are seen. Strike energy in composite materials only may be absorbed by elastic deformation and some of the injury mechanisms (matrix break, delimitation, fibre break, etc.). In that respect damage resistance expression refers to magnitude of strike injury emerged in a composite system.

Generally, strikes are classified as low speed or high speed, but, among those categories no open transmission is present. Researches carried out depicts that no clear outcome is found yet for the determination of that transmission. Some of the studies performed in that field points out that low speed strike which is available to be considered as static, must be evaluated as speed rates varying in the range of 1 and 10 m s^{-1} speed rate depending on wind speed and material quality, rigidity of blade.

Low speed strikes in normal conditions cause deformation at the contact of wind and blade in the internal structure of the material. In some cases low speed strike is also used as strike carrying low level energy. At low speed strike contact time length required for responding to strike inside the material structure is sufficiently long and as a result, more energy is absorbed elastically. For that reason, dynamic structural respond of turbine blade is crucially important. Respond to fast strike is provided by means of tension wave along material and in that circumstance material does not earn time for responding the strike and injury is applied to very small region. So that, fast speed is determined by fibre break in the form of disruption, low speed is determined by delimitation between layers and matrix break.

Loading situation where composite materials are mostly susceptible is the one towards the out of plane. Because, they are weaker compare to layer plane in the direction of thickness. As a result, composite materials exposed to strike in width direction undergo important injuries leading to decreases in total load carrying. Composite materials responds for that strike loads are very complex. It also depends on each of the component's own properties constituting a composite material and structural configurations. In addition, respond given to strike is also depending on the geometry, speed and mass of the hitting wind. Each of them plays an important role for defining characteristics of strike total effect in width direction.

CONCLUSION

In following years in the future, polymer composites are estimated to take place in turbine blade technologies. For that purpose, studies on stronger and more rigid fibers and more heat resistance, not causing cracks, high strike resistance and tough polymer matrix form are anticipated to be carried out. In addition, with classically known composites intelligent composites in turbine technology may be thought in economical way. Therefore, primarily tension emerged in turbine blades, heat and perception of strike senses will be possible to gain from wind energy related to that. By means of intelligent composites decrease of danger factor, control of structural vibration will be possible to provide and as a result high magnitudes of energy gain will be available to generate. Moreover, through implementation of such materials to some extent, entirely controlled structures on wind turbine blades will be provided by means of perception, conversion of energy to useful energy along entire surface, control of every point.

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