International Workshop on

NATURAL AND LOW-COST MATERIALS IN WIND ENERGY TECHNOLOGIES

10-12 November 2008, Dhulikhel, Nepal.

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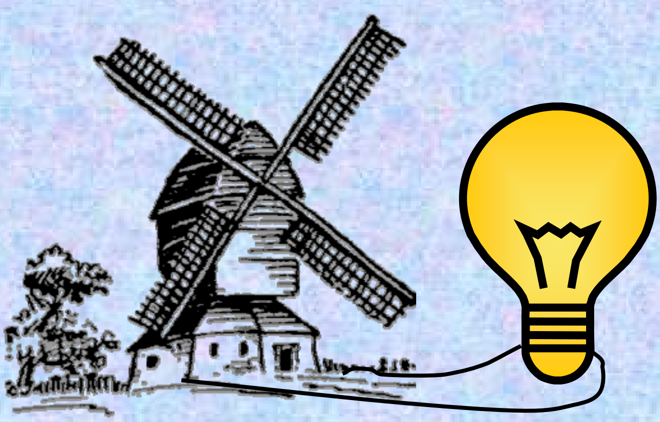


PROGRAMME AND ABSTRACTS




Overview and Objectives

The renewable energy technologies can provide sources of unlimited, cheap and clean energy to the people in developing countries. Especially, communities in hilly and dry regions, which do not have easy access to the hydro power, and can not afford the installation of long transmission lines or using solar photovoltaic power, could benefit from the wider use of wind energy. Small wind turbines can present a good, economically viable and environmental friendly solution to provide remote villages in hilly areas with light and electricity.

In order to reduce costs of wind turbines and to make this technology more attractive for developing countries, the natural, locally available materials, notably wood, can be used to produce parts of the wind turbines instead of or along with conventional composite materials.

The Workshop focuses on perspectives, and on scientific and technical aspects of using low cost, and natural materials, in particular, wood, in wind energy technologies. The analysis and prediction of strength and reliability of wooden parts, as well as interrelations between wood microstructures, mechanical properties and performances and computational modelling of natural materials and their properties are also important topics for the Workshop.

The symposium takes place at the Himalayan Shangri-La Hotel, in Dhulikhel (http://www.dwarikashimalayanshangrila.com/).

Workshop Topics

The workshop covers the following main themes:

- Low-cost wind energy technologies, their perspectives and applications in developing countries,
- Mechanical testing, strength and reliability of wood, other natural and low-cost materials, used in wind energy technologies,
- Mechanics and micromechanics of natural materials, optimal choice of materials and coatings for wind energy technologies,
- Case studies, social and economic aspects of wind energy in developing countries.

Organizing Committee

Povl Brøndsted (Risø.DTU, Denmark)
Peter Freere (Monash University, Australia),
Dorte Juul Jensen (Risø.DTU, Denmark)
Leon Mishnaevsky Jr. (Chairman) (Risø.DTU, Denmark)
Rakesh Sinha (KAPEG, Nepal)
Parash Acharya (KAPEG, Nepal)
Rakesh Shrestha (Practical Action, Nepal).

Proceedings

Selected papers presented at the Workshop will be published in a special issue of the Journal of Wind Engineering (http://www.ingentaconnect.com/content/mscp/wind).

Programme

November 10, 2008

9:00- 10:00	*Registration*
10:00-12:00	**Opening Session**
10:00-10:05	Opening, Leon Mishnaevsky Jr. (Denmark)
10:05-10:15	Welcome, Povl Brøndsted (Denmark)
10:15-10:25	Welcome, Rakesh Sinha (Nepal) and Peter Freere (Australia)
10:25-10:35	Welcome, Jun Hada (Practical Action Nepal)
10:30-10:50	*Coffee*
10:50-11:20	Low cost small wind turbines: the interaction of materials, design, and manufacturing, David Wood (Australia)
11:20-12:00	Wind energy: Materials challenges now and in future, Povl Brøndsted (Denmark)
12:10-14:00	*Lunch*
14:00-16:20	**Session on Small Wind Turbines in Nepal and other Developing Countries**
14:00-14:40	Case study of the development in Kenya of the third generation Kijito wind pump, Mike Harries (Kenya)
14:40-15:00	Small wind system market and institutional model for Nepal, Rakesh Shrestha (Nepal)
15:00-15:20	*Coffee*
15:20-16:00	Scenarios of renewable energy, its opportunity and challenges in Nepal, Ramesh Maskey (Nepal)
16:00-16:20	Starting a technical business in Nepal, Peter Freere (Australia)
16:20-16:40	Wind Resources Map of Nepal, Aruna Awale, (Nepal)
17:00-18:00	*Visit to the site of wooden wind turbine at Dhulikhel*
19:00-21:30	*Dinner*

November 11, 2008

9:30-12:00	**Session of Wood Properties**
9:30-10:10	What makes wood stiff and tough? Ingo Burgert (Germany)
10:10-10:30	Fracture, hardness and fatigue testing of wood: KAPEG experience, Rakesh Sinha (Nepal)
10:30-10: 50	3D Micromechanics of wood: a way to classification and choice of wood for structural applications, Hai Qing (Denmark)
10:50-11:20	*Coffee*
11:20-11:40	Diagnostics of small cracks in woods for rotating parts, Alla Balueva (USA)
11:40-12:00	Bamboo: Perspectives of its application in wind energy constructions, John W. Holmes (Denmark)

12:00-14:00	*Lunch*
14:00-16:20	**Session on Wind Energy in Nepal and other Developing Countries**
14:00-14:40	Small wind farm: Lighting up rural Nepal, Rakesh Shrestha (Nepal)
14:40-15:00	Case study of the wind based rural electrification project in Esilanke Primary School, Kenya, Baptiste Berges (Denmark)
15:00-15:20	Coffee
15:20-15:40	Performance of hand carved timber blades on a small wind turbine, Phil Clausen (Australia)
15:40-16:00	Wind energy in India – A perspective, Anumakonda Jagadeesh (India)
16:00-16:20	Community based wind electrification schemes in Sri Lanka, Namiz Musafer (Sri Lanka)
16:20-16:40	Experience and prospects of wind power in Belarus, Alexander Mikhalevich and Vladimir Pachkov (Belarus)
16:40-18:00	Visit to KAPEG site
19:00-21:30	*Dinner*

November 12, 2008

9:30-12:00	**Session on Design of Small Wind Turbines**
9:30-10:10	Designing small wind turbines using the IEC simple load model, Phil Clausen (Australia)
10:10-10:30	Design aspect of composite blades for wind turbine– delamination, Homayoun Hadavinia (UK)
10:30-10:50	Design aspects of a Small Wind Turbine adapted to powering a rural school in Kenyan wind climates, Baptiste Berges (Denmark)
10:50-11:00	Closing Remarks, Leon Mishnaevsky Jr (Denmark)
11:10-11:20	*Coffee*
12:00-14:00	*Lunch*

ABSTRACTS

(Alphabetically, according to the first authors family name)

Wind Resources Map of Nepal

Aruna Awale, AEPC, Nepal

Global warming and climate change is one of the most challenging serious and hot issues in the world today. Nepal being rich in renewable energy resources could play an important role to face these challenges. Among other resources, wind could become a major source of renewable and climate friendly energy if it could be exploited and implemented in a large scale. In case of Nepal it could even solve the present load shedding problem to some extent. The wind energy development plan was however introduced in Seventh five year Plan, the continuous efforts have been taken by government sector only after establishment of AEPC with the activities such as data collection, research and development and wind mapping. Though the government has a target to generate 50 kW in this tenth plan, not much has been done in the generation side. AEPC has executed a Solar and Wind Energy Resource Assessment Project (SWERA) with the Country co-partner Centre for Energy Studies. It was funded by United Nations Environment Program/Global Environment Facility. Though the twenty three months project started in March 2003, it was completed only at the end of December 2007 due to lack of available ground measurement data. AEPC has collected wind measurement data at 10m and 20m heights from the ground during this project in five different regions of country and on the basis of these data, Risø National Laboratory, Denmark provided wind map by Karlsruhe Atmospheric Mesoscale Model (KAMM). On the basis of KAMM data base with the technical help from TERI (Technical co-partner of SWERA), Nepal has prepared the solar and wind resource mapping of Nepal by geographical information system (GIS). Hence this paper attempts to disseminate the output of the SWERA project which will help scholars, planners, stakeholders, policy makers, national and international investors and decision makers to create an environment for the development of wind sector.

Key words: Climate change, Solar and Wind Energy Resource Assessment, KAMM, modeling, stakeholders, GIS

Diagnostics of small cracks in woods for rotating parts

A. V. Balueva, Gainesville State College, Mathematics Department, Gainesville, Georgia, USA

Diagnostic waves are intensively used for nondestructive control method for finding localizations of very small damages. In this paper the method is formulated for a notched Euler-Bernoulli beam. Perturbation technique is used to formulate the boundary value problem. It is considered that the depth of the damage, hn, is much smaller than the width of the beam, H, and the wave propagation of the damaged beam is believed to be a perturbation of response of undamaged beam with a small parameter, ε = hn / H. First the problem is solved for undamaged beam, and then this solution is used as a right-hand side for finding of the first, ε, approximation of perturbed part of the solution. We believe that the damage is small enough, and we neglect the second, ε2, approximation. The numerical solution is based on recently developed the Spectral Element Method (SEM), which is the Finite Element Method specially modified for wave propagation problems in finite length structures. Novelty of this method is that the stiffness matrix elements are calculated analytically in Fourier transform, and all computations are then performed in frequency domain without returning to the initial space. The proposed method may be used for exact identifying of small damage parameters such as width, depth, and location.

Case study of the wind-based rural electrification project in Esilanke Primary School, Kenya

Baptiste Berges, Suzlon, Denmark

The electrification of Esilanke Primary School is a project developed by the Danish wind energy consulting company KenTec and its Kenyan partner Windgen and was funded by the Danish International Development Agency (Danida).

The ultimate goal of this wind-based electrification pilot project was to contribute to assessing the feasibility and the conditions of viability of wind-based decentralised electrification in rural Kenya.

In March 2007, a 1kW China-imported wind turbine and battery storage system was installed in Esilanke School by the Kenyan windpump manufacturer Bobs Harries Engineering Ltd. Thanks to the excellent wind resource (6.89 m/s mean wind speed at 10 agl), the amount of energy produced by the turbine much exceeds the school consumption on a yearly basis. Some energy shortage (a few days to a few weeks a year) might however happen during the low wind season.

The project has induced several socio-economical benefits since the education standards have been improved with notably better lighting, the reduction of kerosene use and cost, the development of morning/evening classes, and the access to computer equipment. An income generating activity (mobile battery charging) has been initiated which has already enabled to collect sufficient amount for next battery distilled water replacement.

This project has enabled to learn the following key lessons:

1) the viability of the Small Wind Turbine (SWT) business model in Africa and their affordability for rural communities require the development of an expertise and sales network throughout Kenya;
2) provided training, there is no technical barrier for the use of SWT system in rural electrification projects: rural communities are capable to manage O&M themselves; the proximity of an expertise contact point would however reinforce the technical sustainability on a project life perspective;
3) the impacts on social development are very interesting since SWTs can produce adequate amount of energy with business rural needs and therefore be connected with productive uses and income generating activities.

Design aspects of a Small Wind Turbine adapted to powering a rural school in Kenyan wind climates

Baptiste Berges, Suzlon, Denmark

This study has focussed on the evaluation of the design characteristics of small wind turbine (SWT) adapted to powering a rural school in Kenyan wind climates. The first step has required a deep analysis of the Kenyan wind regimes. It has resulted in establishing the characteristics of typical low and high Kenyan wind climates and build time series.

Simple, robust but high performance power systems being the key for sustainable rural electrification project, the generator choices have been restricted to direct driven Permanent Magnet Generator technology. The energy demand for a Kenyan rural school accessing to electricity has been assumed to 2 kWh/day.

The present study has then consisted in assessing the influence of various design parameters (airfoil, rotor diameter, number of blades, pitch, yaw offset and generator) on the power and starting performance of 300W and 850W rated wind turbines thanks to the classical Blade Element Momentum method (BEM) from Glauert.

After providing the blade geometry and the generator power and efficiency data as inputs, the developed code enables to determine the operating conditions (CP, □ vs V0) and to simulate the starting sequence of the turbine.

It has been demonstrated in this study that a well-designed 300W wind turbine can already provide 60% of basic rural Kenyan school electricity needs in low wind climate, and up to 90% if the rotor is oversized for the given generator. In high wind climate, the wind turbine would produce much more than the basic needs. A small wind turbine rated at 600W at 9m/s provides 130% of rural Kenyan school electricity needs in low wind climate.

One important conclusion is that high power production and starting performances are not antagonist objectives: increasing chord length distribution, Rtip or blade number are interesting strategies to meet those both objectives. Adjusting root design is decisive. The project enhances that the generator choice is a key step in the SWT design process.

What makes wood stiff and tough?

Ingo Burgert, Max-Planck-Institute of Colloids and Interfaces, Department of Biomaterials, Potsdam, Germany

Wood is well known for its excellent mechanical properties despite its low density. From a materials science point of view it is mainly the unique combination of stiffness and toughness that makes wood a widely used biomaterial and inspires new biomimetic fibre composites. The macroscopic properties of wood emerge from the organization of the cell walls due to the hierarchical organization of the tree. At the micro- and nanostructural levels trees manifest a wide variety of adaptable parameters such as cell shape, thickness and arrangement of cell wall layers, the orientation of cellulose microfibrils within cell walls, and in the chemical composition of individual cell wall layers. In terms of its composition and architecture, the wood cell wall can be characterized along the lines of a fibre-reinforced composite [1] by means of stiff semi-crystalline cellulose microfibrils embedded in a compliable amorphous matrix of hemicelluloses and lignin [2]. The talk reviews the current knowledge on the structure and mechanical design of wood cell walls with a specific emphasis on interactions of cellulose fibrils and matrix polymers [3,4,5]. Parameters of wood selection with regard to potential applications in the field of wind power stations are discussed.

[1] Fratzl P, Burgert I & Gupta HS, *Phys. Chem. Chem. Phys.*, 2004, **6**, 5575-5579.
[2] Fahlén J & Salmén L, *Biomacromolecules* 2005, **6,** 433-438.
[3] Burgert I, *Am. J. Bot.*, 2006, **93**,1391-1401.
[4] Gierlinger N, Schwanninger M, Reinecke A & Burgert I, *Biomacromolecules,* 2006, **7**, 2077-2081.
[5] Keckes J, Burgert I, Frühmann K, Müller M, Kölln K, Hamilton M, Burghammer M, Roth SV, Stanzl-Tschegg SE & Fratzl P, *Nature Materials*, 2003, **2**, 810-814.

Wind Energy. Materials Challenges now and in future.

Povl Brøndsted, Risø National Laboratory for Sustainable Energy, Technical University of Denmark, Roskilde, Denmark

Renewable energy resources, of which wind energy is prominent, are part of the solution to the global energy problem. Wind turbine and the rotorblade concepts are reviewed. Typically the blade consists of two shells giving the desired aerodynamic profile. The main part of the load carrying structure will normally be included in the shells. Between the shells and the beam one or more web(s) are normally inserted, often build as sandwich structures. The web(s) will support the shells against buckling and can also form a part of the main load carrying structure. Unsupported parts of the shells - especially the large panels between the trailing edge and the rear web - are normally built as sandwich structures. The critical properties of the structure are the shear and the stiffness and strength (static and fatigue). Damage progress and damage tolerance are important subjects to consider in estimation reliability of the blades.

The load carrying materials of rotor blades for wind turbines are usually made of fibre-reinforced plastics or wood. The materials are typically made from E-glass and carbon fibres impregnated with a thermosetting resin (polyester, vinylester or epoxy). Blades made of wood are either surface treated natural wood or wood impregnated with epoxy.

The fibers and matrices for composites are described, and their high stiffness, low density, and good fatigue performance are emphasized. Manufacturing technologies for composites are presented and evaluated with respect to advantages, problems, and industrial potential. The important technologies of today are prepreg (pre-impregnated) technology and resin infusion technology. Material properties depend strongly on the fibre architecture and content, and the chosen processing route. The mechanical properties of fiber composite materials are discussed, with a focus on fatigue performance. Damage and materials degradation during fatigue are described.

The mechanical behavior of composite materials is influenced by a variety of parameters. The homogeneity and quality of the materials manufactured are essential. Defects such as wrinkles, misalignment, and porosities formed during the manufacturing process can lead to failure mechanisms such as fiber fracture, interface cracking, and matrix cracking, which are sources for microbuckling, translaminar crack growth, and delaminations. These failure mechanisms have essential influence on the resulting properties, and it is the obtainable material quality that sets the limits for the mechanical properties and their variations. From a basic materials approach the mechanical properties are controlled by the damage initiation and the damage evolution.

Testing procedures for documentation of properties are reviewed, and fatigue loading histories are discussed, together with methods for data handling and statistical analysis of (large) amounts of test data. Future challenges for materials in the field of wind turbines are presented, with a focus on thermoplastic composites, new structural materials concepts, new structural design aspects, structural health monitoring, and the coming trends and markets for wind energy.

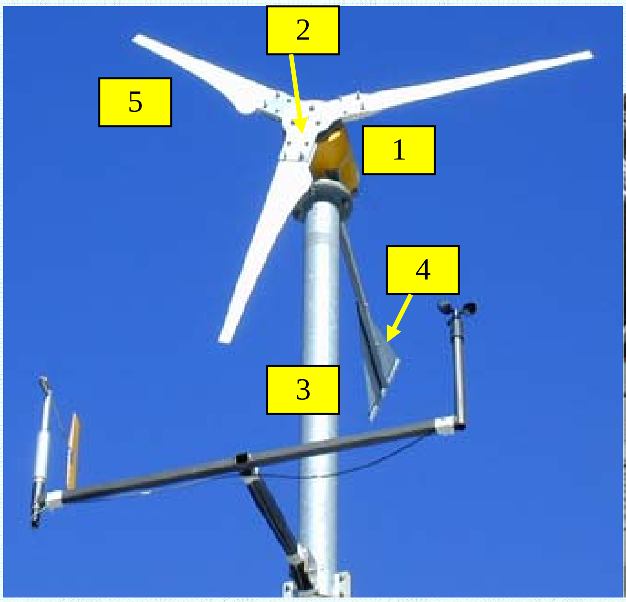
Designing Small Wind Turbines Using the IEC Simple Load Model

P.D. Clausen[1], P. Peterson[2], S.V.R. Wilson[2], D.H.Wood[1,2]

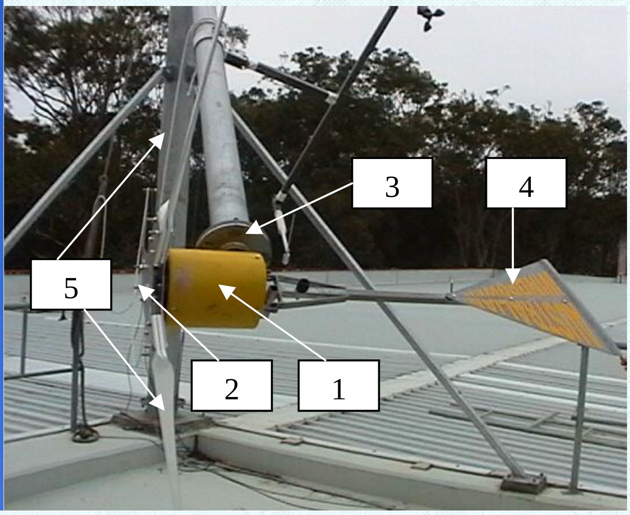
[1] School of Engineering, University of Newcastle, NSW 2308, Australia

[2]Aerogensesis Australia www.aerogenesis.com.au

The latest edition of the International Electrotechnical Commission (IEC) standard for the safety of small wind turbines1 allows the assessment of turbine safety through three alternative paths. The first is by use of the “simple load model” (SLM) which uses straightforward formulae and large safety factors to determine the important turbine loads, those on the blades and the main shaft, in comparison to the allowable material stresses. The second is by use of an expensive “aeroelastic” computational analysis of turbine response to random changes in wind speed and direction. Thirdly, the standard accepts actual load measurements in lieu of the preceding, but this is obviously only possible at the prototype or demonstration stage of a wind turbine project.



The 500 W turbine (photos by Andrew Wright and Jason Brown)



1. Generator (under yellow cowling): 2. Hub Assembly: 3. Yaw Axis: 4. Tail Fin: 5 Blades

At the design stage, the first two paths only are available, however, for turbine designers with limited resources, only the first is possible. In this paper we discuss and review the SLM and apply it to a 500 W wind turbine that we have been operating successfully and safely at the University of Newcastle since 1999. The turbine is shown in the accompanying figure. The paper will highlight a number of limitations of the SLM as well as the areas of particular concern to the designer. As expected, the SLM identifies the blades and main shaft as the most critical structural component so we explore its implications for

[1] IEC 61400-2:2006 Wind Turbines - Part 2: Design requirements for small wind turbines

the use of low cost and natural blade materials such as timber. We demonstrate by example that timber can be an excellent blade material provided its material properties and fatigue behaviour have been established. Our work on establishing the properties of two Australian timbers will be described.

Performance of Hand Carved Timber Blades on a Small Wind Turbine

P.D. Clausen[1], P. Freere[2], P. Peterson[3], S.V.R. Wilson[3], D.H.Wood[1,3]

[1] School of Engineering, University of Newcastle, NSW 2308, Australia

[2]KAPEG, Dhulikhel, Nepal; Dept. Elec. Eng., Monash University, Victoria 3800, Australia

[3]Aerogensesis, Australia

Experience shows that the most difficult components of a small wind turbine to manufacture are the blades and the generator. Most large wind turbines have moulded composite blades made using techniques such as vacuum infusion. For small and especially micro-turbines (swept area less than 2 m2) geometric accuracy becomes harder to achieve because of the high cost of machining very accurate moulds. Furthermore, in developing countries, there can be problems in importing the large number of necessary composite materials. For example, the 2.5 m long blades for the new 5 kW Aerogenesis turbine2 require eighteen specific consumables for their manufacture. On the other hand, timber is much more likely to be available in the required sections and lengths. To ensure maximum geometric accuracy, timber blades should be machined either on a computer controlled milling machine or by using an accurate copying jig and a master blade. This level of technology is often not available in developing countries but a readily-available alternative is to hand carve blades using a master as a guide. Manufacturing blades in this manner is obviously a compromise that can only be justified if any loss in performance is relatively small. Three 1 m long blades for a 500W micro-turbine were copied from a master blade by a craftsman at a furniture factory in Banepa, Nepal. The hand-carved rotor is due to be tested this year at the University of Newcastle with the test program ending in October. The power curve determined from the hand carved blades will be compared with that from composite blades made accurately from moulds cut on a computer-controlled milling machine. The final paper will describe the tests and any differences in performance.

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[2] See "Advanced Blades for Small Wind Turbines", P.D. Clausen, P. Peterson, S.V.R. Wilson, D.H. Wood presented at Solar '07, ANZSES Conf. 2007.

Starting a Technical Business in Nepal

P. Freere[1], C. Lamichhane[2], G. Shrestha[3], P. Ghimire[4], R. Sharma[5], R. Sinha[5], P. Acharya[5]

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5. KAPEG Pvt Ltd, Dhulikhel, Nepal

The general issues of starting and operating an engineering business in Nepal are presented, together with explanation of the effects of the culture, economic and political situation. Practical solutions are discussed as well as the legal and administrative arrangements required to operate a business. The effects of the geographical location on the business are illustrated, together with the impact of a low technical base. These issues will be shown to form a basis of an opportunity for business and social cohesion. Staffing issues are drawn upon to show how a business can have a beneficial effect on the development process of an area. With little government direction of the economy or higher education, considerable efforts in staff training is required. Starting a technical business in a very low capital economy directs the business towards a high labour input with consequences for productivity and repeatable product quality. Consequently, low profit margins hinder capital investment, creating a barrier to feeding an export market with high quality goods. The present influx of low cost Chinese made goods into Nepal challenges companies towards specialised products and services.

A case study of a local engineering business is presented to illustrate the above points. Various solutions will be discussed, as well any final solution. Presently, the company has been relying on one off development contracts and a discussion will be presented as to how to broaden its financial base, so that it may provide a future for highly trained engineers in Nepal and contribute to the wealth and health of Nepal.

Small Wind Energy System: Lighting Up Rural Nepal

Jun Hada, Rakesh Yogal Shrestha, Practical Action, Lazimpat, Kathmandu, Nepal

In many parts of Nepal, there is a high potential for wind energy application. Electrification is feasible by taking advantage of opportunities in wind energy technology in those scattered rural settlements where wind is abundant and, where there is no possibility of grid connection in near future. Practical Action Nepal has tested various small-scale wind power plants in seven such windy hills of Nepal taking an approach of decentralized community management system. Both stand alone and group installations were tested primarily to address the lighting needs of isolated poor families of rural Nepal. This paper will focus on how small wind energy system can be considered as a viable alternative as

clean and renewable energy option for poor isolated people. It will look into the existing barriers and challenges to develop and promote small scale wind energy technology commercially in Nepal. The paper will be centered towards the efforts of Practical Action Nepal on development and promotion of small wind energy technology including building capacities of local entrepreneurs to manufacture and beneficiaries to operate and manage the wind systems in a sustainable way. It will include the aspects of developing product specifications and guidelines for assurance of standards and quality. Likewise, it will also highlight the findings of evaluation conducted during 2004 on socio-economic impacts, technical performance, existing operation, maintenance and management practices, recommended actions and needs for improvement with regard to social, institutional, financial and technical aspects of Practical Action Nepal demonstrated small wind energy systems. Finally, this paper will bring about the facts on how these small wind energy systems though very small have been contributing to reduce the green house gas emission and effects of climate change.

Design Aspect of Composite Blades for Wind Turbine– Delamination

Homayoun Hadavinia, Faculty of Engineering, Kingston University London, UK

The world energy consumption has increased to more than 14 terawatt-years per year while the primary source for production of energy, fossil fuel, depletion accelerating and the world is in the verge of an imminent catastrophe. At the same time the world's population grew just above 6 billion and it will peak around the year 2070, with slightly fewer than 9 billion people living on the planet. The increasing population and expanding use of consumer electrical appliances and wider use of cars in developing country and new emerging economy of China, India and Brazil will cause energy demands in the world to continue to increase and it is vital today to accelerate expansion of a sustainable energy supply together with optimized use of energy consumption and development of new resources with minimized pollution. Wind energy is part of the solution to these challenges.

A wind turbine is a rotating machine which converts the kinetic energy in wind into mechanical energy by turbine blades and subsequently into electricity. The rotor blades are a rather flimsy structure, consisting of cantilever-mounted blades on a central hub. The basic design aspects for a rotor blade are the selection of material and shape. The material should be stiff, strong, and light. The shape should be aerodynamic, similar to that of an airplane wing. The challenge for the designers is to integrate the aerodynamic shape, the tapering and the twist, into a design of the blade structure that is optimized with respect to materials selection and cost-effective production. Rotor blades represent a substantial portion of the cost of intermediate to large-size wind turbines, hence low-cost blades are needed to improve the overall effectiveness of these systems. This is necessary to maximize energy from the available wind conditions. In the design of the blades three sources of load need to be taken into account, i.e. the limit load, fatigue and a rapid shut down in hurricanes. No yielding or buckling of any primary structures under maximum wind load should occur and no failure under the fatigue load in 20 years turbine design lifetime corresponding to 108 to 109 rotation, and the deflection of the blade tip not to cause the blade hit turbine standing column. The optimum blade design will be based on the maximum allowable blade weight and the maximum allowable dead weight static bending moment of the blade. Also the first natural frequency mode range of the blade should be obtained from modal analysis of the blade.

Fibre reinforced plastic (FRP) composite materials have gained popularity in wind turbine blade design due to their flexibility in obtaining the desired mechanical and physical properties in combination with their lightweight characteristic. FRP Composites are now being widely used in large wind turbine blade of up to 70 m length (140 m rotor diameter) where high strength and high stiffness-to-weight ratios are required. Composite materials are usually made of glass, graphite, boron, or other fibres embedded in a matrix. They are heterogeneous materials and have several types of inherent flaws. The analysis of stress and deformation of composite blades is to predict the serviceability, reliability, and manufacturability of blades. In order to make such assessments, the mode (or modes) of failure are required to be known and accounted for. Failure of fibre composites is generally preceded by an accumulation of different types of internal damage. Failure mechanisms include fibre breaking, matrix cracking, interface debonding and delamination. Laminated composite structures are made up of orthotropic laminae that are bonded together. Due to the lack of reinforcement in the thickness direction and, also, since interlaminar stresses exist in the boundary layer of laminates under transverse loading, the layers are likely to debond, and delamination is one of the prevailing forms of failure in laminated composites. Delamination can occur during the manufacturing process due to contaminated reinforcing fibres, by insufficient wetting of fibres, or by shrinkage that occurs during the curing of the resin or the subsequent service life of the laminated part. The presence and growth of delamination in laminates reduces significantly the compressive load-carrying capacity of a structure by lowering the resistance to out-of-plane buckling of the groups of plies to either side of the delamination and causes initiation of catastrophic failure. Delamination can also grow under cyclic fatigue loading, with catastrophic failure occurring if the delamination reaches a critical size.

Fracture mechanics is concerned with crack-dominated failures and delamination is a fracture mechanism of composite laminates. Therefore, fracture mechanics is a suitable methodology to approach the onset and propagation of composite delaminations problem. In addition, usual composite laminates are very stiff in the laminate plane and behave as linear elastic materials in their gross deformation. Therefore, it is reasonable to base the analysis of interlaminar toughness on linear elastic fracture mechanics (LEFM). In this study various test methods for characterising different Mode of composite delamination will be discussed.

Case Study of the Development in Kenya of the Third Generation Kijito Windpump

Mike Harries MA (Cambridge), Chairman and Managing Director, Bobs Harries Engineering Ltd (BHEL), Karamaini Estate, P O Box 40, Thika, Kenya

Allen Charles Harries brought his family from South Africa to Kenya in 1904 and settled 50 kms north of Nairobi at Karamaini, where the family still farms today. In 1961 his grandson Mike returned from Cambridge University with a wife Pauline, and a Degree in Agriculture, and having completed his Military Service joined the family agricultural business under his father Bobs.

In 1971 the family acquired a 4 seater Cessna aircraft, and Mike volunteered free a month of his working year to a small Christian Mission called "Sight by Wings" that specialized in flying volunteer eye surgeons from Kenya and overseas to the remotest parts of East Africa. During these challenging safaris Mike discovered the crucial role that hygiene played in the prevention of such awful diseases as Trachoma, which children could so easily contract, and go blind from, because there was not sufficient water for them in these arid areas to wash their faces. The mucus around their eyes attracted flies, and that was how they could easily contract the disease.

At the same time Kenya was facing power shortages from their mainly hydro generated power due to drought. This got Mike thinking about ways of raising water in these areas with windpower. The family heard about an initiative by the Intermediate Technology Development Group (ITDG) of Britain who were interested in contacting entrepreneurs in several Countries to help them develop a new concept of windpump, that did not involve castings and gears. Initially six Countries expressed interest: Kenya, Botswana, Egypt, Oman, India and Pakistan, but it was only Kenya (through BHEL)that was prepared to put in the necessary hard work and finances to augment the assistance from what was then ODA, to carry out a six year Research and Development Programme. This was assisted by Mike Neale and Associates of Farnham, England, and resulted in taking a very rudimentary basic shallow well design from ITDG, to the range of deepwell machines that BHEL make today.

During these last 27 years the family has faced many problems in keeping the whole concept alive and has had to largely subsidise the project by selling off part of the family farm. A family policy of not paying bribes made it almost impossible to get Government contracts, and until recently few people have taken seriously the possibility of incorporating windpower into part of their water pumping needs. However oil at over $100 a barrel and concern for the environment and global warming have vindicated the family's initiative to give the well proven technology a new look, with a fabricated transmission that can be manufactured in small quantities in a relatively simple rural workshop. To this end BHEL has recently opened a workshop for making Kijitos in Hargeisa, Somaliland, with a Somali friend. Mike and his daughter Tracy employ some 30 people and to date the Company has installed 400 Kijitos in East Africa and beyond and have exported to some 12 other Countries.

Bamboo: Perspectives of its application in wind energy

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The use materials such as wood as a load bearing structural member in wind turbine blades is primarily limited to small wind turbines or in a limited number of larger hybrid blades manufactured from birch with glass and carbon-fiber reinforcement. The limited supply and high cost of birch has led to a search for other renewable materials that can be used for wind turbine blades. Bamboo has many engineering and environmental attributes that make it an attractive material for utilization in wind turbine blades. This paper examines the mechanical properties of a novel bamboo-poplar epoxy laminate which is being developed for use in wind turbine blades. Information provided in this brief paper include an overview of the laminate construction and initial data for the of the and monotonic tensile and compressive stress-strain behavior of panels formed by hot-pressing. In addition, a discussion of fracture resistance of the laminate, under Mode I and Mode II loading conditions is provided. General recommendations regarding the future use of bamboo-based composites for large MW size wind turbine blades are also presented.

Wind Energy in India – A Perspective

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The Wind power programme in India was initiated towards the end of the Sixth Plan, in 1983-84. A market-oriented strategy was adopted from inception, which has led to the successful commercial development of the technology. The broad based National programme includes wind resource assessment activities; research and development support; implementation of demonstration projects to create awareness and opening up of new sites; involvement of utilities and industry; development of infrastructure capability and capacity for manufacture, installation, operation and maintenance of wind electric generators; and policy support. The programme aims at catalyzing commercialisation of wind power generation in the country. The Wind Resources Assessment Programme is being implemented through the State Nodal Agencies, Field Research Unit of Indian Institute of Tropical Meteorology (IITM-FRU) and Center for Wind Energy Technology (C-WET).

Wind in India are influenced by the strong south-west summer monsoon, which starts in May-June, when cool, humid air moves towards the land and the weaker north-east winter monsoon, which starts in October, when cool, dry sir moves towards the ocean. During the period march to August, the winds are uniformly strong over the whole Indian Peninsula, except the eastern peninsular coast. Wind speeds during the period November to march are relatively weak, though higher winds are available during a part of the period on the Tamil Nadu coastline.

A notable feature of the Indian programme has been the interest among private investors/developers in setting up of commercial wind power projects. The gross potential is 45,000 MW (source MNES) and a total of about 8757.2 MW of commercial projects have been established until March 31, 2008.

Globally, the wind energy sector saw phenomenal growth in the year 2007. However, in India, the industry failed to keep pace. Worldwide wind energy installation were 19,696MW in 2007 up from 15,120 MW in 2006. In contrast in India the installations in 2007 were 1580 MW down from 1730 MW in 2006.

Though India ranks 4th globally, the country managed to register a growth rate of just 25.2 per cent against the world average of 26.6 per cent. This puts India far behind countries like the US (45 per cent), Spain (30.2 per cent), France (56.7 per cent), and its neighbor China (127.5 per cent). India's total installed wind energy capacity now stands at 7,850 MW in comparison with 6,270 MW in 2006 and 4,430 MW in 2005.

According to Dr Anil Kane, president, World Wind Energy Association, "The last year was very successful for the wind industry worldwide. However, there are several developments that make us feel concerned: 20 of the top 40 markets have decreased the volume of additional capacity and only 18 countries have been able to increase their size".

In the year 2007, 19,696 MW of new wind energy capacity was added summing up to a global installed capacity of 93,849 MW by the end of December 2007.

Identifying and prioritizing barriers is an important prerequisite to kick off small wind turbine technology in India. This subject is considered in this presentation as well.

Experience And Prospects Of Wind Power In Belarus

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Apart from peat, Belarus lacks significant fuel resources including natural gas, oil and coal. Nevertheless it has essentialy energy intensive economy. In 2003 the share of the industrial sector (including construction) in the GDP was 32%, transport and communication – 11%, agriculture – about 10%.

Further Belarus must follow Russia in affiliation to Kyoto Protocol. This opens up for a double solution, improving of energy independency and reduction of greenhouse gases emission by extending the use of renewable energy resources using the Kyoto Flexible Mechanism of Joint Implementation. In December of 2004 the Aim Program of the Using of not less than 25% of Domestic Fuel Resources and Renewable Energy Sources for Production of Power and Heat to 2012 ("Program 25%") was approved.

The average annual wind velocity in Belarus is less than 4 m/s and in majority of sites it changes from 3 to 4 m/s. Nevertheless 1840 "windy sites" in the country have been found with average wind speed of 5.5-6.5 m/s near the ground and 6.5-7.5 m/s at the height of 40 m.

Taking into account the moderate wind conditions in Belarus the new type of wind turbine has been developed on the basic of Magnus effect. It was equipped with rotating cylinders instead of conventional blades. The efficiency of this turbine has been demonstrated during testing of pilot unit with capacity of 100 kW. At present the second unit with capacity of 250 kW is under operation not far from Minsk city (Fig.1).

The wind turbine design and manufacture enterprise "AEROLLA" was founded in Belarus about ten years ago. Except rotary the conventional wind turbine with capacity of 75 kW was developed and produced for farms and other local consumers. The cost of this turbine is approximately US$ 75-85 thous. To reduce this cost the ten-module unit with capacity of 10 kW each was developed (Fig.2). It is expected that cost of this type of turbine in Belarus will be 500-550 EURO/kW.

Figure 1. Picture of rotary wind turbine with capacity of 250 kW

Figure 2. Module wind turbine with capacity of 75 kW

Community Based Wind Electrification Schemes in Sri Lanka

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Key words: Community wind electrification schemes, households, consumer collective,

Sri Lanka is a developing island nation with nearly 20m million inhabitants. It adopted an open economic policy in 1978, after which the demand for energy has been on the increase. In 2003, its primary energy supply was 9,122 kilo Tons TOE, biomass, petroleum, hydro and non conventional renewable energy contributing 48%, 43% 9% and 0.03% respectively. About 75% of the population has access to national electricity grid, per capita average electricity consumption is 369 kWh. The installed electricity generation capacity in 2006 was 2,429 MW, from which over 50% generated was by burning fossil fuels. The demand for electricity escalates at nearly 10% per year. To increase the installed capacity, there are plans to introduce coal fired plants totalling 1,100 MW. Sri Lanka has only one grid connected wind farm of 3 MW capacity commissioned in 1999 while a recent study has revealed that the country has a potential of 24,000 MW of electricity from wind at 50m above the ground. Currently, 4 more wind farms are in the pipe line.

In addition to the only grid connected wind farm in Sri Lanka, there are about 50 household level small wind systems and 3 more community based wind electrification schemes catering to the remote areas, where the national electricity grid is unlikely to be extended in the near future. The first community based wind electrification scheme experience was in 1998, and the latest was in 2006. The community based electrification schemes are operated by the communities themselves. After about 6 years, the area where the first wind electrification scheme was installed got access to national electricity grid, and the consumers switched on to it and the turbine system was relocated in a village about 350 km away.

In a community wind electrification scheme, the community members in the villages team up with the implementing partners and work together in setting it up. There is a direct contribution by the consumers, by way of supplying and erection of poles for the distribution lines and the house wiring etc. The implementing partners such as the catalyst, research institutions and the social mobilising CBOs contribute with their experience and expertise on community wind electrification technology & approach. Major expenses are met by the donor.

A typical scheme provides each household with about 200 W of electricity for about 4 hours a day depending on the wind availability in the season. Scheme caters to about 12-15 households. The homes are not metered and consumers are not charged on the amount of electricity consumed. Instead, use of bulbs and appliances are checked and controlled by a special consumer collective made up of villagers. Only the lower energy consuming devices are used. Each household makes a monthly contribution for the maintenance of the electrification scheme determined by their collective.

Conclusions: There are many hamlets in windy areas in the off-grid areas. It leads to a considerable potential to promote wind energy being an environment friendly technology. Both state and private sector are keen in this option. The experiences gained from hydro and biogas sectors have been adapted to promote community based approach to wind energy for electrification. Experience has been gained on how these schemes are planned, implemented, integrated into the social systems, local value additions, how technical and after sales supports are extended and the economics of this type of interventions.

3D Microstructural Model of Wood: Analysis of Microscale Mechanisms of Deformation

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A 3D hierarchical computational model of deformation and stiffness of wood, which takes into account the structures of wood at several scale levels (cellularity, multilayered nature of cell walls, composite-like structures of the walls layers) is developed. At the mesoscale, the softwood cell is presented as a 3D hexagon-shape-tube with multilayered walls. The layers in the softwood cell are considered as composites reinforced by microfibrils (celluloses). The elastic properties of the layers are determined with Halpin-Tsai equations, and introduced into mesoscale finite element cellular model. With the use of the developed hierarchical model, the influence of the microstructure, including microfibril angles (MFAs, which characterizes the orientation of the cellulose fibrils with respect to the cell axis), the thickness of the cell wall and the shape of the cell cross-section, on the elastic properties of latewood was studied.

Fracture, hardness and fatigue testing of wood: KAPEG experience

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This paper explores some of the properties of different kind of timbers available in Nepal, with a view to construct small wind turbine blades. Static test performed on different timbers, with a purpose built four point bending test rig, provides some insightful knowledge about the usefulness of those timbers. Turbine blades should be capable of withstanding aerodynamic loading. Comparison of different parameters like Young's Modulus and Bending strength for different timber species are presented in detail in the paper.

Weathering test results are also an important factor in determining the life of the wooden blades. Different timbers specimens are exposed under natural conditions to understand their behaviours. The results vary within a sample of same species and among different timber types. The results are included in the paper. Also, another important parameter, hardness properties have been compared among different samples and the issues of large deviation between measurements are addressed.