C-WET

pavan

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A news bulletin from the Centre for Wind Energy Technology, Chennai

editorial . . .

Windy season is here. With more than sixty percent of energy generated coming from these three to four months, a kind of purposefulness from the wind industry's O & M groups is palpable in the air. These are more vehicles and crane movements in the wind farming areas and persons virtually camping at substations. It gives a good feeling to think that the days of hoping for a break are over and Indian wind industry means business. I of course do hear glib statements about winds being about 20% less than last year, setting the stage for justifying lower generation, just in case. If the anticipated generation levels are anyway touched, one could always feel happier that the machines have been improving their performance over the years! This gut feeling business is virtually sorcery. As such, the insecurity of wind industry makes it difficult to explain that anything naturally occurring has a large component of natural variability and it is beyond wishful thinking. Just to draw parallels, notwithstanding very involved and high-funda modeling, monsoon prediction invariably goes through a series of amendments even as monsoon advances and recedes. Only here, there is no direct private sector financing involved and (forgive me for using the word) rash promises. One has to accept nature's bounty as it comes. One should not take an unreasonable position that notwithstanding wind conditions; one has to get so many units of electricity from one's wind farm.

This brings us to the need for more careful pre-assessment. Invariably, there seems to be a need for educating customers of wind power hardware that they should not look upon wind turbines as they would look at a diesel generator set. Things will be acceptable only so long as exactly diesel prices can be passed in to the manufactured product without loosing markets. In the face of international competition this is completely unacceptable. Just imagine a situation where oil becomes very scarce. Then can we expect to run our generating sets. At least wind or hydroelectric power, there is a fair chance of getting something every year. In order to minimize such risks, data has been collected painstakingly over many decades and modeling techniques and availability of trained man-power to effectively apply these tools are on hand. There is always a market need that needs to be balanced with scientific tools and efforts should be towards minimizing consequences of over expectations by a very strict pre-project scrutiny. This will avoid unfortunate post-mortems at a future date.

M.P.Ramesh, *Executive Director*

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About 20% of TN power from renewable energy OUR ECONOMY BUREAU

With 2,317 mw installed capacity, about 20% of the power generation capacity in Tamil Nadu is from renewable energy sources, against the national average of 4.8%. The state has almost 30% of the all-India renewable energy capacity of about 6,000 mw. "Thus Tamil Nadu continues to be the number one state in power generation through renewable energy sources in the country", Mr R Viswanathan, the minister for electricity and transport.

He said Tamil Nadu was actively pursuing a strategy to tap the renewable energy sources from wind, biomass and biofuels. "The Minister said the government was not only aiming at promotion of renewable energy in rural areas as energy sources, but also promoting them to increase employment opportunities and augment the income of rural populace".

Tamil Nadu had fixed a target of adding 500 mw from wind power for the 10th Plan (2002-07), which has been surpassed with capacity addition of 1,173 mw in the first three years alone, he said,. He was addressing the inaugural session of the two-day conference on 'Green Power 2005', organised by the Confederation of Indian Industry (CII).

"TN, with a capacity of 2,040 mw as on March 31, 2005 accounts for more than 55% of the total installed capacity of 3,600 mw from windmills in the country". The State Government has taken several initiatives to utilise biomass for power generation. The Tamil Nadu Energy Development Agency (TEDA) has recommended 37 biomass based power projects to TNEB for a total capacity of about 260 mw. Approval has been given for 15 projects for a capacity of 145 mw by TNEB so far.

The State Government has also been assisting industries to install biomass gasifiers for thermal and electrical applications, he said. "Now the government is encouraging production of bio-fuels such as ethanol and bio-diesel, which will help us in many ways to reduce the cost of power, reduce input of crude oil, prevent pollution on the one hand and increase employment opportunities in rural areas", he said.

Source : www.financialexpress.com

RECORD INSTALLATION OF 1,111MW IN INDIA DURING 2004-2005

During the financial year period of April2004 –March2005. India Witnessed about 1,111MW capacity addition of Wind Power, Which is the highest in any financial year so far. The Cumulative installation till March 2005 was 3, 595 MW as compared to cumulative installed capacity of 2,483MW at the end of 2003-04. The growth in 2004-05 was almost 44%. With this addition, India is likely to rise to the fourth Position in the world, overtaking Denmark.

Wind Energy Can alone meet World's Electricity demand

The world energy demand could be met entirely from wind energy. Their study analysed wind Measurements from 7,5000 weather stations and 500 weather balloons to develop a Comprehensive " World Map of Wind" that should assist climatologist in choosing effective locations for new wind forms.

World wide with sustainable class3 winds (6.9 m/s) desirable fir economic profitability were equipped with wind power stations, 72 terawatts of electricity could be produced.

This would amount to more than 40 times the total global energy consumption in the year 2000.In comparison it would take 500 nuclear plants and thousands of coal power plants to produce the sane amount of energy –christina Archer and Mark Jacobson of stanford University in california.

Leading Industries, PSU's in India look at investment in wind Energy

Big Corporations such as the Tatas, the Aditya Birla group, PRG Enterprises, the Godrej group and several leading textile mills have started investing in wind Power Projects. State Wise win installations in India during the year 2004-05

Tamil Nadu	675MW
Karnataka	201MW
Rajasthan	106MW
Gujarat	52MW
Maharastra	49MW
Andhra Pradesh	22MW
Mathya Pradesh	6MW
Total	1,111 MW

Wind energy is the best option amongst non-conventional sources

Good economics, safety makes it an attractive proposition

Last year an Indian company announced that it would be setting up a 24 mw wind farm at a project cost of Rs. 120 crore. This works out to an investment of about $1.2 per watt, which is very significantly lower than the other tried and tested non-conventional source of renewable energy, namely solar photo voltaic cells, where the initial investment is still as high as $5-$8 per peak watt.

One continues to hear lot of noise about renewable sources of energy, but in reality there is very little on the ground. Despite the fact that we need to add almost 100,000 mw to our installed power capacity in the country, we are probably not serious about exploring full potential of the alternate sources. Considering the initial investment on solar energy, this option is obviously not feasible till some revolutionary changes take place and the cost of photo voltaic cells drops down to the region of $1 per peak watt. However, at Rs 50 per watt investment, wind energy certainly seems to be an eminently feasible option, especially considering the fact that the investment figure of about $1 million per mw is more or less the same as that for conventional thermal power plants.

There is of course the question of wind speeds in large parts of India and number of hours for which the wind turbines would be operational so as to determine the expected output of energy from a particular installation over, say, a whole year. Typically, one could look at about 500 hours per annum in Rajasthan and in Tamil Nadu. I am not sure if data is available for many other regions of the country, where there are good wind speeds.

Detractors of non-conventional energy sources might well argue that at such a low utilisation level (500 to 1,000 hours per annum), which represents only about 5-10 % of the total time, we are grossly over-estimating the utility of such installations. However, one should not ignore the fact that first, these installations do not cause any environmental pollution at all. Second, there are no recurring costs unlike in a thermal plant where, coal and diesel constitute huge inputs, in addition to the cost of maintenance and of course, the headaches of gross pollution and fly ash disposal etc. And finally, solar cells also don't collect energy 24 hours a day!

We need to have a serious look at a third option also. Here I am referring to bio-mass energy. Considering the fact that we have a cattlehead population of about a billion which generate probably one to two billion tonnes of gobar annually, we are literally staring in the face of a huge source of energy. Theoretically, if all this could be processed in bio-gas plants, it would not only add significantly to our energy generation but would also produce huge quantities of nitrogenous fertilisers. Of course, there are major problems in this area too. Most of our cattle population is of the free-grazing type and as such collection of gobar could well prove to be an insurmountable task. To top it all, gobar gas plants require continuous supply of water, which is scarce even for the purpose of drinking. There are not many dairy farms with large population of cattle and most of the people own only one or two animals.

At one point of time, KVIC was actively working on studying this option by producing low-cost gobar gas plants. In principle, one kg of wet gobar generates 175 (1/6th of a unit) watt hours of electrical energy. So, where are we heading on the energy scene. The government is of course furiously working on augmenting the installed capacity in the country by putting up more thermal plants. No doubt, it is an old tried and tested method and procedures are in place to minimise the gaseous and solid pollution generated by thermal plants, but does that mean the end of the road for other sources of energy?

We don't even seem to be serious about hydel energy which is once again perennial, involves no ongoing raw material cost and causes no pollution. Will we never find a way to tackle our self-appointed activists who have managed to delay the Narmada project by a decade or more. Why don't we seriously look at the option of mini and micro hydel plants like what China has done. This would also not pose the problem of dislocation of people and tampering with the environment. Finally, what about atomic energy. One of the most successful examples of commercial exploitation of this source is France which produces perhaps 85% of all its energy needs by this method. In addition to France, many other European countries are also successfully exploiting this source of energy. We may, of course, have to address the issue of international inspections and other such political matters.

Having looked at all possible non-conventional areas of producing energy, it appears that wind offers the cheapest and safest source. Hence, a government policy is needed on this subject to give a major push for augmenting our energy capacity.

Source : www.financialexpress.com

Work at C-WET

DEVELOPMENT IN R&D UNIT

Modeling of Interconnection of the wind turbines with the grid:

The R&D Unit carried out real time measurements at a sub-station with wind-turbine feeders for the validation of the model to study the 'Interconnection of wind turbines with the grid',

Measurement set-up at sub-station

Parameters like wind speed, voltage, frequency, active power, reactive power, power factor were recorded during steady state and fault conditions.

Study of acoustic emissions of wind turbines

The Unit is also carrying out a study on "Acoustic emissions of wind turbines".

Measurement in progress ......

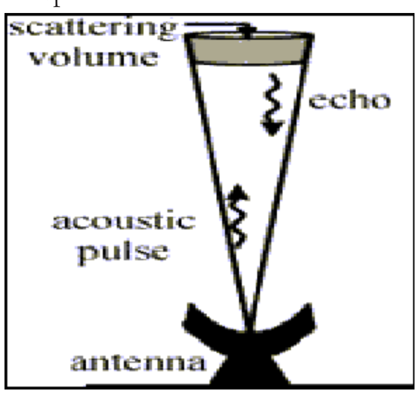
Measurements were carried out on a wind turbine at Kayathar. This will help in understanding the influence of the turbine characteristics on the acoustical performance.

Study of flow pattern in Palghat gap

A Sonic Detection and Ranging System or Sound Detection And Ranging system (SODAR) was procured for carrying out a project on 'Study of flow pattern in Palghat gap'.

SODAR

SODAR is an instrument for the measurement of wind velocity. It is a remote sensing system for the measurement of the wind profile and stability classes in the lower atmosphere. The principle of operation is to send acoustic pulses vertically and at a small angle to the vertical. These are then scattered by temperature and humidity fluctuations and gradients in the atmosphere.



Principle of a SODAR

The received signals are analyzed in terms of frequency shift produced by the Doppler effect. The scattering intensity is plotted as a function of height and time. The resulting echograms give patterns of the temperature structure, which indicate whether the conditions are stable, unstable or neutral.

A 'Water Pumping Wind Mill' has been installed to harness wind power for pumping water. The cut-in speed of the windmill is 1.5 m/s. At 1.5 m/s wind speed the rotor requires approximately 6 seconds for one rotation.

In this low wind, the rotation is slow and the volumetric efficiency is 0.5. With a progressively increasing wind speed / rotor speed the volumetric efficiency also increases until it reaches 0.9 at a wind speed of 3.5 m/s. At wind speeds above 3.5 m/s the volumetric efficiency will remain 0.9.It pumps 2.7 litres/stroke when volumetric efficiency is 90%.

Water Pumping Wind Mill

Besides these, a project on 'Determination of dynamic characteristics of a 250 kW capacity wind turbine rotor blade' was carried out by an M.Tech student under our guidance. Two undergraduate students were imparted training on 'Basics of Wind Turbine Technology'.

MOVE ON IN WRA UNIT

Wind Monitoring in the Northeastern region:

Under Ministry of Non- Conventional Energy Sources Special Programme of Wind Resource Assessment in the NE region of the country nine wind monitoring stations with 25m tall masts were commissioned in four states of the region as follows

1. Assam - Tolpoi
2. Manipur -Laimaton & Kotlane
3. Mizoram -Lunglei & Mamte
4. Arunachal Pradesh - Likabali, Raga, Sela &Rupa

Ministry Sanctioned 20 more Wind Monitoring Stations

The Ministry of Non- Conventional Energy Sources has sanctioned a project to take up Wind monitoring studies at 20 monitoring stations in 10 States with 50m tall masts with instruments at 3 levels. The states to be covered under the program are Tamilnadu, Karnataka, Andhra Pradesh, Maharashtra, Madhya Pradesh, Gujarat, Uttar Pradesh , Himachal Pradesh, Jammu& Kashmir and Assam.

STEPS FORWARD IN TESTING UNIT

The measurements for Professional Type testing of Pavan Shakthi 600 kW wind turbine at Coimbatore and Enercon 800 kW at Bamnasa in Gujarat are currently in progress. The measurements of NEPC 750 kW wind turbine in Tamilnadu is expected to start in the beginning of July 2005. The unit also had signed with M/s NEG-Micon for Power curve measurements of 950 kW wind turbine at Chitradurga, Karnataka in April 2005. The project is currently in progress.

MARCHING AHEAD IN S&C UNIT

The renewal of PTC of VESTAS V39-500 kW with 47 m rotor diameter has been completed and certificate was issued, which is valid until 20.04.2006.

The Renewal of PTC of NEPC-225 kW has been taken up.

Current Activities:

- The certification projects taken up as per TAPS 2000 is under progress.
- The continual improvement and maintaining the Quality Management System are on going.

HIGHLIGHTS FORM ITCS UNIT

National training course: C-WET is planning to organise a third national training course on "Wind Farm Development and Related Issues" on 1st and 2nd September 2005 to address all aspects of wind power starting from wind resource assessment to project immplementation and o perations in a focused manner. the idea is to bring out basic and advanced training and knowledge to industry, utilities, technical institutions and various Central and State Governemental implementing agencies. Moreover the course provides an invaluable platform for dialogue and open exchange of views and experiences.

Library Automation: C-WET has established a well-equipped Library in its campus with reference materials, books and periodicals (Magazines and Journals). Every effort is being made to procure literature regarding wind energy sector in particular and renewable energy in general. The work related to the automation of the library is in progress to maintain the library resources and offer the services effectively.

Operation & Maintenance of Wind Turbines—Investor's Role

Any equipment needs care to get the best in its performance & the return on investment. Generally, one gives the attention to the machine when he is not getting expected results. It is more so when one faces such difficulty either in one's personal use of any capital equipment or by a group of machinery to produce a product.

In the case of the wind turbine investment, generally similar required attention is seldom given for several reasons. As long as one gets around (least or assured) the expectation in generation by the end of the year, one is happy. The difficulty is faced when either the cost of maintenance goes high or the revenue from generation falls below the general expectation. By then the year is complete and any analysis or search for cause, shall throw up many reasons. Mainly, it is generally attributed to the wind pattern of that year, or the availability of grid for power evacuation. Unless there was a major component failure, that year, causing turbine being shut for considerable time, it is rare that one goes into details of uptime and seek possible improved performance from the service provider for the turbine under the O & M contract.

It is true that the input for power generation for a wind turbine is free and wind is an act of God (may be scientifically supported reasons are there fro variation year after year) but we can make the best use of what is available under the prevailing conditions, within one's control.

In case, a similar investment like DG set happens to go under break down, not being able to supply power when it is required in an Industry, specially when there is power cut, I am sure the senior management gets this information immediately and gets into act to probe or review seriously at this juncture itself. This stoppage may be affecting the output from the production unit, which can also cause annoyance to its customers for the delay in delivery etc.

In a similar situation of an investment of wind turbines the investor should be able to give attention to force the service provider, to do the necessary for optimum generation.

It may not be economical, always to have his own representative on his roll, to monitor the turbine on day-to-day basis, especially in case of owning fewer turbines. But one can have a process of overall review and get the best generation possible. This approach has also linkage to the purpose of investment, whether for just some financial gains or for real power generation and income.

It is also true that this type of approach of surveillance is really difficult in the case of wind turbines; as such investments are generally located in remote areas, unlike other business units in the vicinity for overall day to-day supervision of senior management. The service provider also has his own limitations in terms of giving the best always. A good understanding has to be established for mutual benefit while deciding the O&M contract.

One of the tools that can be used for better monitoring, what is happening in the their wind farms, is to have cooperation amongst these investors with small number of turbines to share information like what is practiced in Housing societies with periodical meetings and continuously be aware of many issues affecting them. This may also help the service provider for taking up some administrative issues, collectively.

Investor may like to know that in India, the return on investment is not just fully dependent on the turbine selected, micrositing adopted by the developer. The grid, power evacuation, quality of work in the high-tension line for the turbine installations within the wind farm and upto the substation are also playing major role. It is seldom given its due importance. The excuse for uptime of wind farm is linked to this and sometimes failure of small element can cause huge loss of generation. The O&M contract is generally considered to be restricted to the turbine, its associated transformer and switching equipment located near it.

So investor should consider enlarging scope of maintenance upto the near by substation. Even though beyond the DP / metering point officially it is under purview of the Electricity Board, only service provider can do a better job. The EB response and the repair work content again depend on the service provider. With some incentive in the O & M contract for better uptime (excluding the forced shutdown by EB) there is lot to gain in terms of generation.

In other countries this dependence is less on such grid elements, as they prefer to go for underground cables within wind farm. Today they also are trying to use dry transformer not only to reduce generation losses but also to get better grid availability. The investor should insist on the service provider classifying the loss of generation into machine down time and grid non-availability. There can be clear distinction between what could have been within the scope of repairs and the faults or disruption in the hands of EB. This needs to be closely examined to get optimum generation.

The conclusion is that there may be opportunity for the investor to get more revenue, without any additional recurring costs, if more interest is shown to the details of what is really happening in the wind farm. This shall also help to unearth some specific or unique issues related to his wind turbines or the region, but may not be common to all others.

A.S.Karanth,
CEO, BF Utilities Ltd. , Pune.

WIND TURBINE COMPONENTS FATIGUE

Introduction:

What is fatigue?

Fatigue is a form of premature failure that occurs in structures when it subjected to dynamic and fluctuating or varying load. Under these circumstances failure can take place at a stress level lower than the tensile or yield strength for a static load. Which never reaches a level sufficient to causes failure in single application

The term fatigue is used because this type of failure normally occurs after a lengthy period of repeated stress or strain cycling. The fatigue failure may advance suddenly without any warning.

Purely static load is rarely observed in engineering components or structures. Majority of structures involves parts subjected to fluctuating or cyclic loads. Repeated loads, fluctuating loads and rapidly applied load induces fluctuating cyclic stress. This cyclic loading causes fatigue failure. 80-95 % of all the structural failure occurs through a fatigue mechanism. The damage occur during fatigue process is cumulative, it is unrecoverable.

Fatigue process actually embraces two domains of cyclic stressing or straining that are distinctly different in characters. In each of these domains, failure happen by apparently different physical mechanism.

Domain I

Plastic straining: This involves large loads and short lives and usually referred to as low-cycle fatigue.

Domain II

Elastic Region: Stresses and strains are largely restricted to the elastic region. This domain is associated with low loads and long lives and is commonly referred to as high cycle fatigue. The nominal stress method does not work well in the low cycle region where the applied strains have significant plastic component. in this region a strain based methodology must be used.

Stress cycles:

The applied stress may be

a) Axial (tension, compression),

(b) Flexural (bending),

(c) Torsional (Twisting).

In general, there are three different fluctuating stress-time modes are possible which contribute to the fatigue process

a) Regular and sinusoidal time dependence; In this case amplitude is symmetrical about mean stress level. This is an idealizing loading condition typical of that found in rotating shafts operating at constant speed without over load. This occurs at maximum tensile stress to minimum compressive stress. This is referred to as a reversed cycle (fig1. a)

b) Repeated stress cycle: In this case they are both tensile and so define an offset for the cyclic loading. This occur in general situation where the maximum and minimum stresses are not equal. (fig 1. b)

c) Random stress cycle; The stress level may vary randomly in amplitude and frequency. This is found in real structure.(fig 1.C)

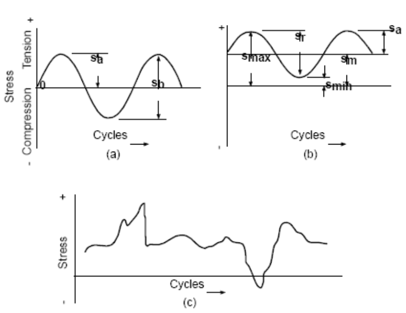


Fig.1

From the above, it is clear that a fluctuating stress cycle can be considered to be made up of two components, a *static* or steady state stress, and an alternating or variable stress *amplitude*, .It is also often necessary to consider the stress *range*, , which is the algebraic difference between the maximum and minimum stress in a cycle.

$$\sigma_r = \sigma_{max} - \sigma_{min} \quad \text{---(1)}$$

The Stress amplitude, σ_a , then is one half the stress range.

$$\sigma_a = \sigma_r / 2 = (\sigma_{max} - \sigma_{min})/2 \quad \text{---(2)}$$

The mean stress, is the algebraic mean of the maximum and minimum stress in the cycle.

$$\sigma_m = (\sigma_{max} + \sigma_{min})/2 \quad \text{---(3)}$$

Two ratios are often defined for the representation of mean stress, the stress or R ratio, and the amptitude ratio A.

$$R = (\sigma_{min} / \sigma_{max}) \quad \text{---(4)}$$

$$A = \sigma_a / \sigma_m = (1\text{-}R) / (1+R) \quad \text{---(5)}$$

Fatigue in Wind turbine components:

Every revolution of wind turbine components (ie rotor, transmission, generator, yaw column) produces a load cycle, known as fatigue cycle. Since the wind turbine components are subjected to repeated loading, failure can occur at a stress level lower than that required causing fracture on a single application load. Due to their complex systems of variable loads, wind turbines are particularly vulnerable to fatigue damage. When enough cycles are experienced, a fatigue crack may develop. Continuation of loading will cause propagation of the crack until get failure. Among other wind turbine components rotor blades are highly prone to fatigue.

Cyclic loading of the structure of a wind turbine may cause failure if some critical level of damage is exceeded. Once initiated, damage grows with load cycling until failure, because either

a) The net section stress (allowing for the loss of section caused by the damage) exceeds the ultimate strength of the material or

b) A critical crack forms by the accumulation of damage.

Fatigue analysis can be done in three methodologies:

1) Stress life or S-N method, commonly referred to as ***total life*** since it makes no distinction between initiating or growing a crack,

2) ***Local strain*** or ***strain-life*** (ε-N) method commonly referred to as the ***crack initiation*** method, which concerns itself only with the initiation of a crack. Fracture specifically concerns itself with the growth or propagation of a crack once it has initiated. Fatigue cracks initiate and grow as a result of cyclic plastic deformation. Without plasticity there can be no fatigue failure.

To find the failure process, S-N method has been used since a long time. In this applied stress is within the elastic range of the material. S-N curves characterized the material or component response to cyclic loading.

3) Linear Elastic Fracture Mechanics

LFEM principles are used to relate the stress magnitude and distribution near the crack tip to:

a) Remote stresses applied to the cracked component

b) Crack size and shape

c) The material properties of the cracked components

If the damage growth rate in a component depends on the cyclic stress range, the load ratio *R* (the ratio of the maximum applied cyclic stress to the material's tensile strength) and the current value of damage *D*, then

Thus the fatigue lifetime, N_f, is the number of load cycles necessary to raise

$$\frac{dD}{dN} = f(\Delta\sigma, R, D)$$

$\Delta\sigma$ = cyclic stress range
R = ratio of maximum applied cyclic stress to the material's tensile strength
D = current value of damage (eg. % of section subject to fracture)
N = number of cycles

the initial damage state D_i to the final or critical level of damage D_f, where failure occurs.

Therefore, by integration

$$N_f = \int_{D_i}^{D_f} \frac{dD}{f(\Delta\sigma, R, D)}$$

$\Delta\sigma$ = cyclic stress range
R = ratio of maximum applied cyclic stress to the material's tensile strength
D = current value of damage (eg. % of section subject to fracture)
N_f = number of cycles at failure

Clearly, it is necessary to define the function *f* in order to quantify N_f. This is commonly carried out empirically by the use of S(stress)-N(cycles) curves(fig 2) . An alternating stress is applied to the material and the number of cycles to failure (*N*) is determined as a function of the stress amplitude (*S*).

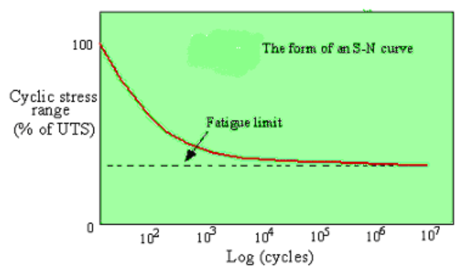


Fig.2

The slope of the *S-N* curve is a measure of the resistance of the material to fatigue, and the actual shape varies from one material to another.

Forces Relevant to Fatigue

Although S-N curves give an indication of relative fatigue properties, they do not take into account the complex effect of the large number of different cyclic forces, which act on a turbine blade during operation. These forces arise due to the blade's own mass and the force of the wind acting upon it. They include the following:

o *Gravitational (due to the pull of the earth on the mass of the blade, causing compression and tension in each cycle)*

o *Centrifugal (due to the rotation of the blade)*

o *Wind thrust (a force perpendicular to the plane of the blade which varies relatively slow)*

o *Rapidly varying forces arising from wind turbulence which increase as stall conditions are approached*

Fatigue Properties of Blade Materials

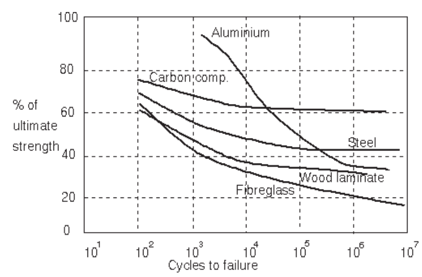


Fig 3

The fig. 3 Shows S-N curves for the turbine blade materials. At this point, it should be stressed that data concerning the fatigue life of materials must be regarded with great care, especially in the case of composite materials where differences in fibre or mat type, matrix/ re-enforcement bond strength or construction methods can introduce significant uncertainties.

The turbine blade material

Composites

The fatigue properties of composite materials depend on the inherent strength and stiffness of their component materials, and on their structure. Glass reinforced composites are the most commonly used turbine blade material. Fig 3 shows a steadily decreasing S-N curve for GRP's, indicating a finite service life. Of the composite materials, those containing higher modulus (stiffer) fibers generally have better fatigue properties, if cyclic stress is applied parallel to the fibre orientation. This is because the matrix epoxy material is constrained by the reinforced fibers during cyclic loading, subjecting the composite to relatively low strains, which do not approach the cracking strain of the matrix. The second phase (such as glass fibre in GRPs) can also act as a crack arresting zone, effectively pinning the growth of fatigue cracks.

Carbon fibre re-informed composites exhibit outstanding fatigue performance when compared to metals and other composites, especially when subject to tension fatigue in the fibre direction. The advantage of CFRPs is reduced when the matrix material becomes the predominant load bearer, but they still offer many times the performance of other composites or metals. At the present time, however, cost constraints mean that carbon fibre composites are rarely used in turbine blade construction.

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C-WET

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