Analysis of Eclipse Gearbox of Wind Turbine for Torque optimization

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ABSTRACT

A wind energy conversion system consists of a number of components to transform the wind energy to electrical energy. The rotor is one of the component of wind turbine that extracts energy from the wind. One of the major component, gearbox is used for transfer high torque generated by rotor to low torque required for generator. Gearbox un-reliability and high repair costs combine to result in critical negative effects on the cost of wind energy production. The Eclipse gearbox is suggested in this project that can significantly reduces gearbox problems occurred in traditional gearbox. The features of Eclipse gearbox is a shortened load path through a single pair of gears combined with linkages and a crankshaft. Multi-stage planetary system of traditional gearbox is reduced to single stage eclipse gearbox, helps to increase speed ratio, long endurance life, small size and light weight. Its size is identical to a traditional gearbox weight reduced to half. Contact stress of gear tooth is substantially lower due the increase in the number of gear teeth that are simultaneously engaged. The minimum tooth contact stress eventually increases the endurance life and torque capacity of the gears.

KEYWORDS: *Wind energy, Eclipse gear box, energy conversion*

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1. INTRODUCTION

With the development of wind power from the rise to the present, there are continuous improvement and updating in technology and the types of the wind unit are variety. According to the way of power adjustment, the horizontal axis wind turbine can be divided into fixed pitch shall-type, variable speed and constant frequency type and the third type can be divided into traditional, direct drive and hybrid. The wind unit is composed by the rotor, pitch system, cabin, gearbox, yaw system, braking system, generator, electrical inverter system, main control system, hydraulic system, tower and foundation and other subsystems and each system has some parts. Wind turbines capture wind energy through wind turbine, transmission system including the main shaft, gearbox and coupling etc. delivered the kinetic energy to the generator, and the generator regulated by the electrical control system issues the high-quality power, then transform the power to gird by the converter and transformer. Control system is the command center of the brain of the power generation, which can control the wind alignment for yaw system, control the converter capturing the maximum wind energy and stable electric power output through the pitch system.

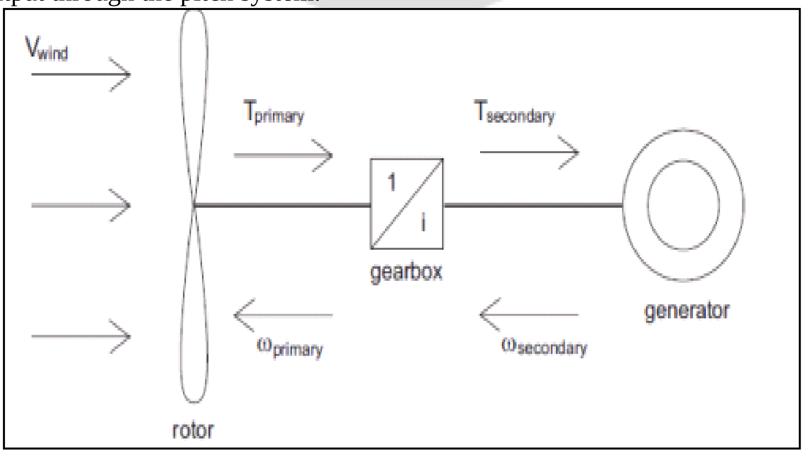

Fig-1: Wind Energy Conversion System

As the long-term work in the wind, rain, snow and other harsh environments, the units may easily lead to the rotor imbalance, blades and hub corrosion, damage and other faults. In contrast, the fault rate of the blades and nub is relatively small. Pitch system regulate the power by changing the blade angle .The pitch system can be divided into hydraulic pitch and electrical pitch by the driving force. Electrical pitch is more flexible and can be easily controlled, so it has a wider use. It changes the blade angle by fixing slewing bearings for pitch drive motor between the blade and hub, which can change the blade lift to control the torque and power of the blade.

Generator transforms mechanical energy into electricity. Generator’s types are various, such as cage induction generator, brushless doubly-fed generator, AC excited generator, synchronous generator. Wind power technology has been developed from fixed pitch wind turbine to variable pitch wind turbine from constant rate control to variable speed and constant frequency control. The wind direction is changing with time, and wind generators must be windward to use the wind energy by maximum efficiency. Therefore, the cabin must also change to follow the changing wind direction to ensure that it is windward and this is realized by the yaw system. Yaw system is an indispensable part of the horizontal axis wind turbine, which plays a very important role in the use of wind. The tower and foundation play a supporting role and it is not only the supporting structural parts of the cabin, but also the installation and maintenance personnel channel for up and down the cabin. Generally the tower should have a certain height to obtain more wind energy.

1.1 LITERATURE REVIEW

R. R. Salunkhe et. al**.** has studied the gearbox is the critical component prone to failure in the load path between the turbine and the generator. Traditional wind turbine gearboxes utilize an indirect path through a multi-stage planetary system. Introduced here is a gearbox that features a shortened load path through a single pair of gears combined with linkages and a crankshaft. The Eclipse Gearbox overcomes the limitations of the planetary gear set and offers a practical, high-reliability gearbox for 200 kW to 10 MW wind turbines.

Terry Lester has studied the linkages are designed with respect to manufacturing tolerances, joint free play and stiffness to maintain evenly distributed linkage loads throughout the Eclipse system, regardless of the loads applied to the windmill blades. The linkages act in parallel to distribute the translational gear loads. The gear loads are distributed over multiple bearings. The bearings in the linkages rotate back and forth about 15 degrees. Only the bearings on the crankshaft and the alignment bearings for the high and low torque shafts rotate a complete 360 degrees.

P.Sakthivel et. al. has studied the wind mill can be divided to two major parts are Mechanical Turbine and Electric Generator. The following section gives a brief description on the Wind Energy System including the main components, design and operation. Among the above the Nacelle is a casing that houses the key components of a windmill such as Gear box, Generator, Electronic Control Unit, Yaw Controller, Brakes, etc. The rotor blades capture the wind's energy and convert it to rotational energy of shaft. The hub in turn transfers the energy to the low speed shaft. Blade designs operate on either the principle of drag or lift. The low speed shaft of the wind turbine connects the rotor hub to the gearbox.

Wind turbine gearbox reliability, premature gearbox failures present major issues in the wind energy industry. Gearbox unreliability and high repair costs combine to result in critical negative effects on the cost of wind energy production. Lost revenues result from long down-times when energy cannot be produced, the substantial expense of the large crane needed to lift a replacement gearbox into place and the cost of the gearbox itself. Combination of large forces and limited bearing size create a critical failure point. Advanced lubrication systems and other planetary gear improvements have not resulted in increased service life. As such, the physical limits of planetary gear sets have been reached. Traditional designs have a finite space for the bearings required to carry the loads of the planetary gears. The large forces creates failure point of gears hence the substantial expense of the large crane needed to lift a replacement gearbox into place and maintenance cost of gearbox.

The gear failure is in two general groups of lubrication-related or strength-related classes. The gear most common types of failure are cited by American gear manufacturing association into seven broad headings of: wear, scuffing, plastic deformation, contact fatigue, cracking, fracture and bending fatigue. Some gear failure modes, particularly in lubrication-related category, are long processes e.g. wear, scuffing and contact fatigue. Tooth fracture may occur under extreme loads or as highlighted by the overloading can create cracks in the root which are later progressing as root bending fatigue cracks with slow propagation. The consequences of failure modes are also not the same. For instance, the consequences of gear tooth fracture due to bending fatigue or overloading are severe. The broken tooth particle damages other teeth and can lead to the gearbox progressive collapse, while pitting damage may only increase the gearbox vibration and noise. According to, the tolerable extent of pitting damage depends on the gear application.

2. METHODODLOGY AND EXPERIMENTAL SETUP

The testing setup of Eclipse gearbox with two linkages is shown in figure 5.1by considering design data and assembly parts. The use of variable speed motor to the input shaft through the reduction pulley for input data and applying different load to the output shafts, taking the readings at different input speed.

Fig-2: Testing setup of Eclipse gearbox with two linkages

For testing purpose we consider low torque shaft as input shaft and by using motor and reduction pulley input is given. At other end i.e. at high torque shaft various loads are applied and change in rpm is noted. The testing is conducted in various three sets, for the first set the motor speed is set at a speed of 5200 rpm. The speed at the motor shaft end and load end are noted by loading the rope by 2 kg initially, the load is increased in steps of 0.1 kg up to a maximum load of 2.5 kg. Once the testing for the first test is over, to start with the second step the speed of the motor is changed to 5500 rpmand remaining procedure remaining the same. Similarly testing for the third step is conducted by setting the speed of the motor to 5800 rpm.

2.2 Testing

The testing is conducted three various set with changes in electric motor speed by regulator and note down changes in speed at output shaft using tachometer as follows,

2.2.1 Reading Set 1 at 5200 rpm Speed

For set 1, Motor speed = 5200 rpm &Input pulley speed =1990 rpm

Table-1: Reading Table for set 1

Sr No	Load	Minimum speed (N1)	Maximum Speed (N2)	N_{mean}
1	2.0	72	80	76
2	2.1	71	78	74.5
3	2.2	69	77	73
4	2.3	68	76	72

5	2.4	67	75	71

Calculations for torque and power o/p

a) At load = 2.0 Kg

Torque Output = W×9.81×R

Where W = Load in Kg, R = Radius of pulley in meter = 0.04 m

$T_{o/p} = 2.0 \times 9.81 \times 0.04$

= 0.7848 N-m

$$\text{Power Output } \left(P_{o/p}\right) = \frac{2\pi N_{mean} T}{60} = \frac{2\pi \times 76 \times 0.7848}{60}$$

= 6.24 watt

b) At load = 2.1 Kg

Torque Output = 2.1×9.81×0.04

$T_{o/p}$ = 0.824 N-m

$$\text{Power Output } \left(P_{o/p}\right) = \frac{2\pi \times 74.5 \times 0.824}{60}$$

= 6.42 watt

c) At load = 2.2 Kg

Torque Output = 2.2×9.81×0.04

$T_{o/p}$ = 0.8632 N-m

$$\text{Power Output } \left(P_{o/p}\right) = \frac{2\pi \times 73 \times 0.8632}{60}$$

= 6.59 watt

d) At load = 2.3 Kg

Torque Output = 2.3×9.81×0.04

$T_{o/p}$ = 0.9025 N-m

$$\text{Power Output } \left(P_{o/p}\right) = \frac{2\pi \times 72 \times 0.9025}{60}$$

= 6.80watt

e) At load = 2.4 Kg

Torque Output = 2.4×9.81×0.04

$T_{o/p}$ = 0.9418 N-m

$$\text{Power Output } \left(P_{o/p}\right) = \frac{2\pi \times 71 \times 0.9418}{60}$$

= 7.01 watt

f) At load = 2.5 Kg

Torque Output = 2.5×9.81×0.04

$T_{o/p}$ = 0.981 N-m

$$\text{Power Output } \left(P_{o/p}\right) = \frac{2\pi \times 70 \times 0.981}{60}$$

= 7.19 watt

2.2.2 Reading Set at 5500 rpm Speed

For set 2, Motor speed = 5500 rpm, Input pulley speed = 2100 rpm

Table-2: Reading Table for set 2

Sr No	Load	Minimum speed (N1)	Maximum Speed (N2)	N_{mean}

1	2.0	76	84	80
2	2.1	74	82	78
3	2.2	73	81	77
4	2.3	71	79	75
5	2.4	70	78	74
6	2.5	69	77	73

Calculations for torque and power o/p

a) At load = 2.0 Kg

Torque Output = W×9.81×R

Where W = Load in Kg, R = Radius of pulley in meter = 0.04 m

$T_{o/p} = 2.0\times9.81\times0.04 = 0.7848$ N-m

$$\text{Power Output}\ \left(P_{o/p}\right) = \frac{2\pi N_{mean} T}{60}$$

$$= \frac{2\pi\times80\times0.7848}{60}$$

= 6.57 watt

b) At load = 2.1 Kg

Torque Output = 2.1×9.81×0.04

$T_{o/p}$ = 0.824 N-m

$$\text{Power Output}\ \left(P_{o/p}\right) = \frac{2\pi\times78\times0.824}{60}$$

= 6.73 watt

c) At load = 2.2 Kg

Torque Output = 2.2×9.81×0.04

$T_{o/p}$ = 0.8632 N-m

$$\text{Power Output}\ \left(P_{o/p}\right) = \frac{2\pi\times77\times0.8632}{60}$$

= 6.96 watt

d) At load = 2.3 Kg

Torque Output = 2.3×9.81×0.04

$T_{o/p}$ = 0.9025 N-m

$$\text{Power Output}\ \left(P_{o/p}\right) = \frac{2\pi\times75\times0.9025}{60}$$

= 7.08 watt

e) At load = 2.4 Kg

Torque Output = 2.4×9.81×0.04

$T_{o/p}$ = 0.9418 N-m

$$\text{Power Output}\ \left(P_{o/p}\right) = \frac{2\pi\times74\times0.9418}{60}$$

= 7.29 watt

f) At load = 2.5 Kg

Torque Output = 2.5×9.81×0.04

$T_{o/p}$ = 0.981 N-m

$$\text{Power Output}\left(P_{o/p}\right)=\frac{2\pi\times73\times0.981}{60}$$

= 7.49 watt

3 RESULT AND DISCUSSION

Consider following graphs of Torque and Power v/s Speed.

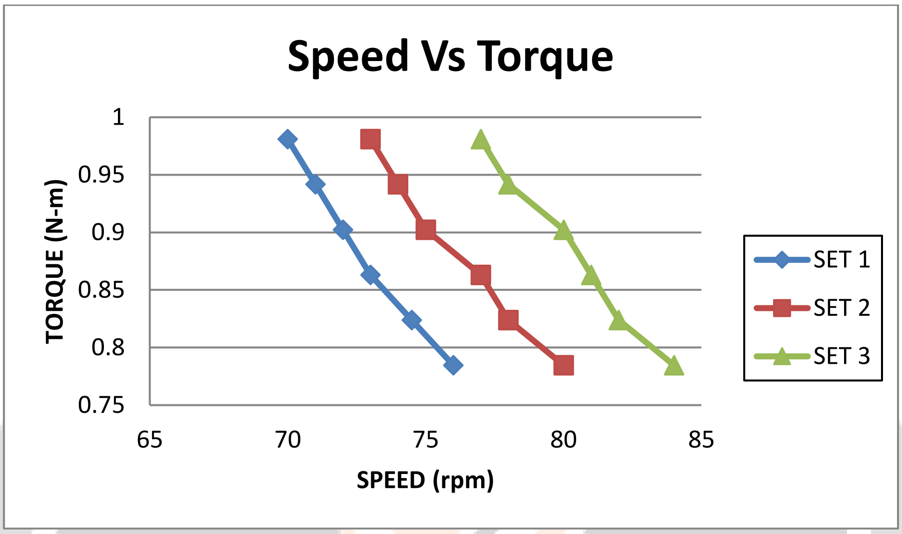

Fig-3: Graph of speed i/p vs. Torque o/p for Sets 1, 2 and 3.

For three successive incremental input speed the output speed (Nmean) obtained was observed. The output speed (Nmean) was observed for different Weight parameter (W) varying from 2.0 to 2.5kg at the same input speed. The observation taken from eclipse gearbox performance based on above mentioned different sets testing observation are noted, with increase in load the torque obtained improves for all three input speeds. It is also noted that, for same weight equal Torque is obtained for all three input speeds. The output speed (Nmean) is reducing with increasing in weight parameter (W) for all three successive incremental inputs.

The first region in wind turbine, the wind speed is not sufficient to rotate the rotor of the wind turbine and it does not produce power because of high torque but from the speed vs. torque graph shows the torque is same for the three different sets results in improving the speed of rotor of wind turbine.

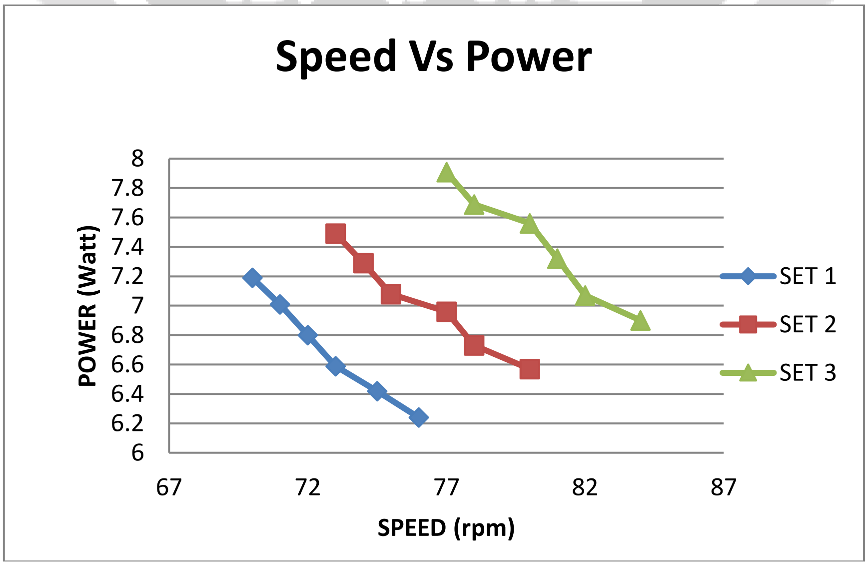

Fig-4: Graph of o/p speed vs. Power o/p for Sets 1, 2 and 3

The performance observed from above experimental analysis on eclipse gearbox with two linkages it is quite clear that, with increase in weight parameter (w) at output pulley the output speed (Nmean) reduces and helps in improving torque. The improvement in torque due to reduction in output speed (Nmean) ultimately results in improving power. The power is depends on the output speed and output power, the output speed increases when increase the motor speed rpm but the testing gearbox is speed reduction gearbox. Hence for the testing purpose parameter is weight and speed from this different reading sets are note down and calculate the output toque.

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