

Experimental Testing of Eclipse Gearbox for Wind Mill Applications

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ABSTRACT: Wind power is currently responsible for about 1:5% of the world's electricity use. Because of this high interest in wind energy, it becomes more and more important to increase the efficiency of wind energy conversion systems (WECS). Such a system consists of a rotor to capture the energy in the wind, a gearbox configuration to speed up the rotational speed of the shaft and a generator to convert the mechanical energy into electrical energy. Blade pitch control is used to control the aerodynamic power captured from the wind. By pitching the rotor blades along their longitudinal axis, the aerodynamic efficiency of the rotor is changed. A disadvantage of using blade pitching below rated speed is that less energy is extracted from the wind, decreasing the efficiency of WECS. Power electronics widely used in the wind turbine industry to improve the performance of wind turbines. The biggest disadvantage of power electronics is reliability. Mechanical components show wear & tear and therefore any failures in these components can be predicted, maintenance can be scheduled before failure occurs. Unfortunately, power electronics do not show signs of degrading, therefore failures cannot be predicted and these sudden failures are very expensive to repair.

KEYWORDS: Crankshaft, Eclipse gearbox, Reliability of gearbox, Traditional gearbox, Wind turbine.

I. INTRODUCTION

Global warming, the increase in the average temperature of the Earth's near-surface air and oceans, is a major issue all over the world. According to the Intergovernmental Panel on Climate Change (IPCC) the majority of the temperature increase is caused by the greenhouse effect. The greenhouse effect refers to the change in steady state temperature of a planet by the presence of an atmosphere containing gas that absorbs and emits infrared radiation. Over three quarters of the greenhouse gas emissions on earth are caused by the combustion of fossil fuels. Renewable energy technologies, such as wind power, solar power, hydropower and biomass, can reduce the emission of greenhouse gases significantly and at the same time reduce the dependency on the oil industry. These two arguments combined make renewable energy a hot item all over the world. The fastest growing renewable energy source is wind power. Wind power is currently responsible for about 1:5% of the world's electricity use. Because of this high interest in wind energy, it becomes more and more important to increase the efficiency of wind energy conversion systems (WECS), also called wind turbines.

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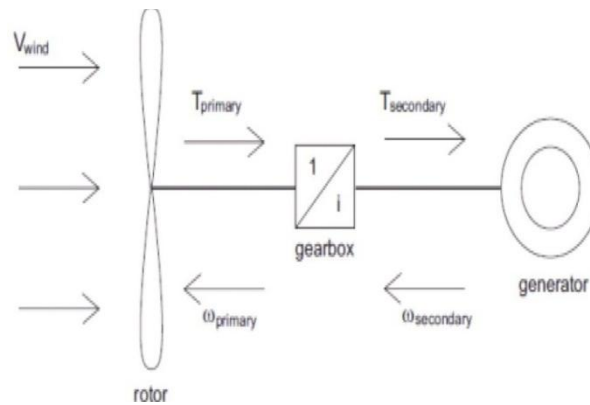


Fig. 1: Wind Energy Conversion Systems

A wind turbine extracts kinetic energy from the wind and converts this into mechanical energy. This mechanical energy is then converted to electrical energy by means of a generator. A wind turbine extracts the maximum amount of energy from the wind when operating at an optimal rotor speed, which depends on the wind speed. Because the wind speed is variable by nature, the optimal rotor speed also varies. Variable speed operation of the rotor results in a higher energy production compared to a system operating at one constant speed. Next to an increase in energy production, variable speed operation enables a reduction in dynamic loads acting on the mechanical component. However, a problem arises when the speed of the rotor varies while the wind turbine must deliver AC power with a fixed phase and frequency to the electrical grid. To match the grid requirements, current variable speed wind turbines incorporate expensive power electronics to convert the variable frequency power to a constant frequency. [1]

II. PROBLEM STATEMENT

POWER ELECTRONICS

Variable speed operation of the generator results in the production of current with a variable frequency. The frequency of the produced current is determined by the electrical angular speed of the generator. For the electrical grid to remain stable, the frequency and phase of all power generating units must remain synchronous within narrow limits. When the frequency of the generator varies too much, in the order of 2 Hz, circuit breakers cause the generator to disconnect from the system, preventing damage to the grid. However, small deviations in the generator frequency can indicate instability in the grid. The grid frequency is not exactly 50 Hz at all times, variations in this frequency directly influence the generator frequency.

Power electronics is a technology that is developing rapidly. Higher current and voltage ratings are available, efficiency increases and costs decrease. Therefore, power converters are widely used in the wind turbine industry to improve the performance of wind turbines. However, there are also a number of disadvantages of using power electronics.

DISADVANTAGES OF POWER ELECTRONICS

The biggest disadvantage of power electronics is the reliability. Mechanical components show wear and tear and therefore any failures in these components can be monitored and predicted, maintenance can be scheduled before failure occurs. Unfortunately, power electronics do not show signs of degrading, therefore failures cannot be predicted and these sudden failures are very expensive to repair. Together with high failure costs, power electronics tend to fail quite rapidly because they are very sensitive to voltage spikes. In the wind energy industry about 25% of all failures is due to the power electronics. [3]

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III. DESIGN OF GEARS

CATIA is used for design of gears. CATIA is increasingly chosen as the primary 3D design system for many companies, the worldwide demand for CATIA designers is difficult to meet. When you learn to use CATIA you also learn to work with leading-edge technology and play an important role in innovation. You get to put your imagination to work at full-speed because with CATIA there are no boundaries.

CATIA enables the creation of 3D parts, from 3D sketches, sheet metal, composites, molded, forged or tooling parts up to the definition of mechanical assemblies. The software provides advanced technologies for mechanical surfacing & BIW. It provides tools to complete product definition, including functional tolerances as well as kinematics definition. CATIA provides a wide range of applications for tooling design, for both generic tooling and mold & die.

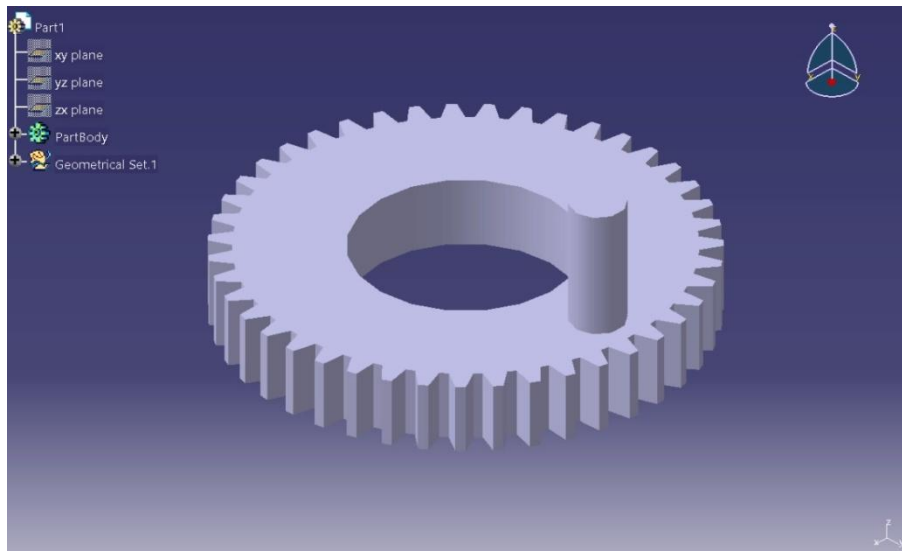


Fig. 2: Design of Internal Gear

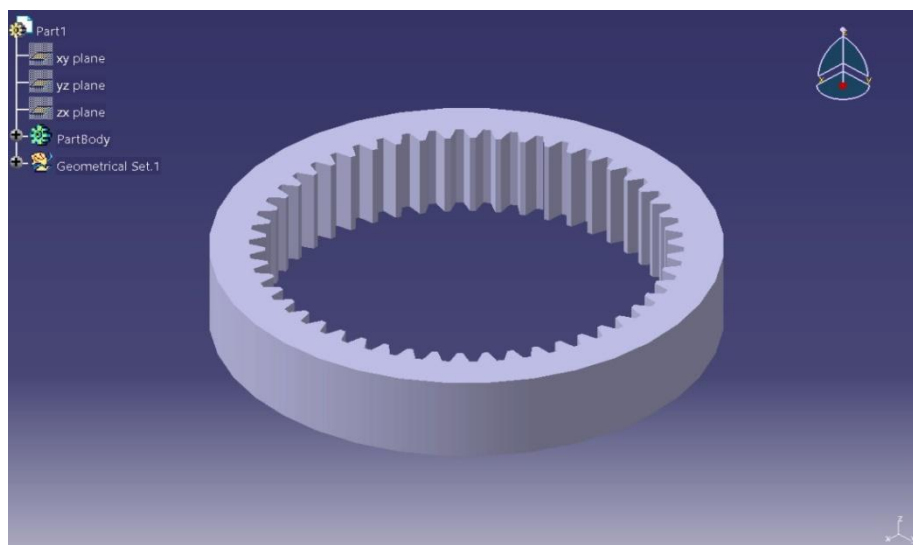


Fig. 3: Design of External Gear

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DEVELOPMENT OF THEORY

A) System Design:

System design mainly concerns with the various physical constraints and ergonomics, space requirements, arrangement of various components on the main frame of machine, no of controls, position of these controls, ease of maintenance, scope of further improvement, etc.

B) Mechanical Design:

This part includes the design and development of linkages, selection of suitable drivemotor, strength analysis of various components under the given system of forces. In Mechanical design the components are categorised in two parts.

- Design parts
- Parts to be purchased

For design parts detail design is done and dimensions thus obtained are compared to next highest dimension which are readily available in market this simplifies the assembly as well as post production servicing work. The parts are to be purchased directly are specified & selected from standard catalogues.

C) Fabrication:

Suitable manufacturing methods will be employed to fabricate the components and then assemble the test set up.

D) Testing:

Testing activity will be done with view to comment on the capability of the machine as regards to the power transmission ability, efficiency and bearing life.

E) Facilities available:

The following facilities to carry out fabrication work are available at sponsor's site.

- Centre lathe
- Milling machine
- DRO – Jig Boring machine
- Electrical Arc Welding
- Electronic Speed Variator
- Tachometer.

IV. EXPERIMENTAL RESULTS

EXPERIMENTAL SETUP

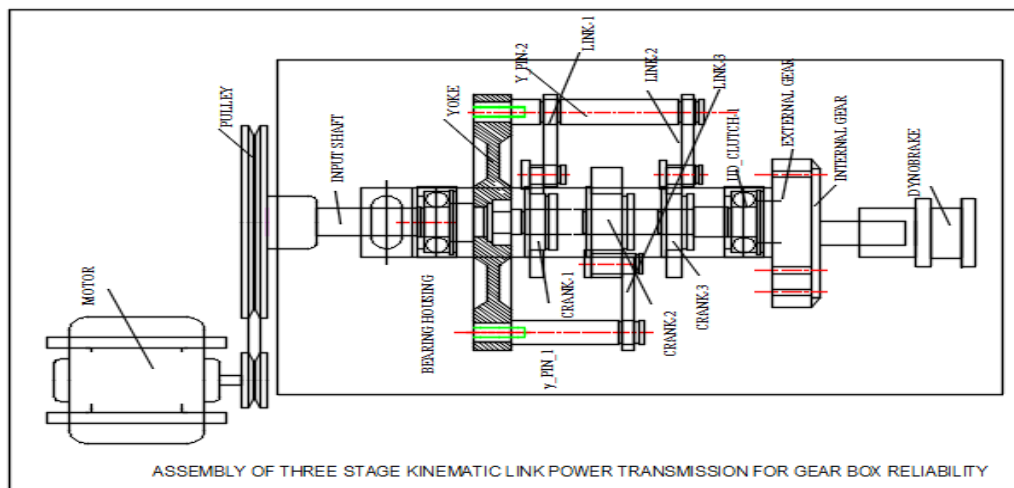


Fig. 4: Test Rig for Experimental Set Up

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TESTING

For testing purpose we take low torque shaft as i/p shaft then by using motor and belt input motion is given. At other end i.e. at high torque shaft, various loads are applied and note down changes in speed at output shaft using tachometer as follows.

Result Table

| Sr. No. | Load (Gm) | Speed (RPM) | Torque (N-m) | Output Power (Watts) | Efficiency |
|---------|-----------|-------------|--------------|----------------------|------------|
| 1 | 120 | 2000 | 0.047088 | 9.8633664 | 56.36209 |
| 2 | 170 | 1875 | 0.066708 | 13.099784 | 74.85591 |
| 3 | 220 | 1545 | 0.086328 | 13.968993 | 79.82282 |
| 4 | 270 | 1390 | 0.105948 | 15.423839 | 88.13622 |
| 5 | 320 | 1250 | 0.125568 | 16.438944 | 93.93682 |
| 6 | 370 | 1030 | 0.145188 | 15.662204 | 89.49831 |
| 7 | 420 | 830 | 0.164808 | 14.32654 | 85.78766 |
| 8 | 470 | 750 | 0.184428 | 14.486819 | 82.78183 |
| 9 | 520 | 660 | 0.204048 | 14.104614 | 80.59779 |
| 10 | 570 | 595 | 0.223668 | 13.93817 | 79.64668 |

GRAPHS OF TORQUE, POWER, AND EFFICIENCY V/S LOAD

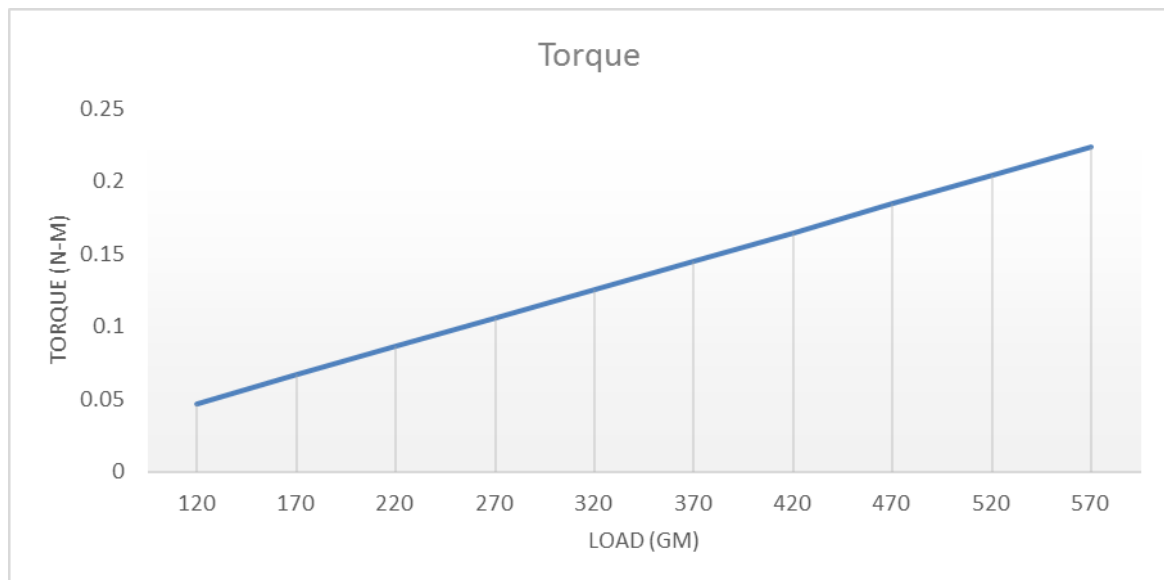


Fig. 5: Graph of Torque Vs Load

Torque is a measure of how much a force acting on an object causes that object to rotate. Figure shows the comparison of torque with load. It can be observed that with increase in load the torque increases with maximum torque of 0.223668 N-m for maximum load of 570 gm.

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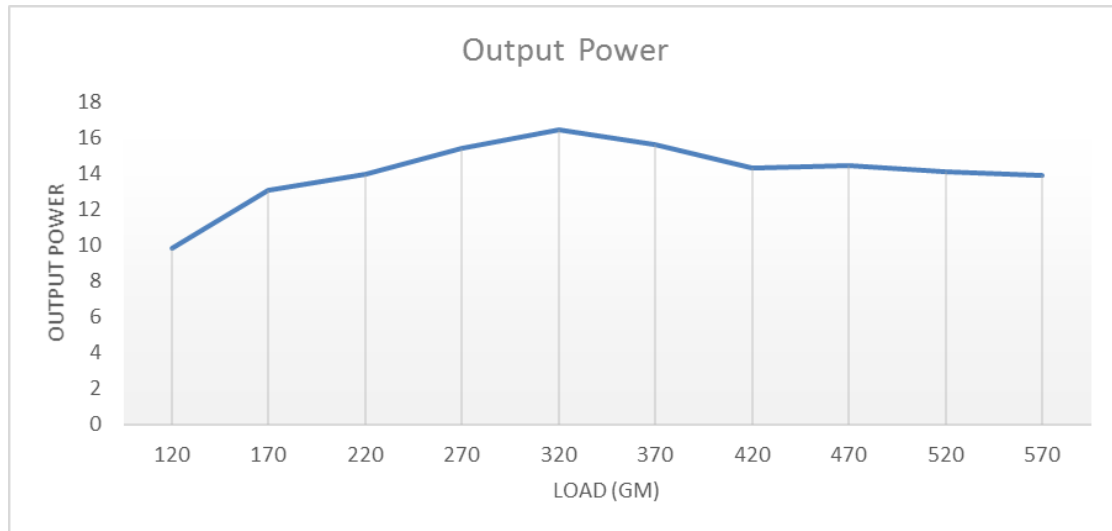


Fig.6: Graph of Output Power Vs Load

Power is the rate of doing work. It is the amount of energy consumed per unit time. Figure shows the comparison of output power with load. It is seen that first with increase in load output power increases up to 16.438994 at 320 gm load. Further increase in load decreases the output power.

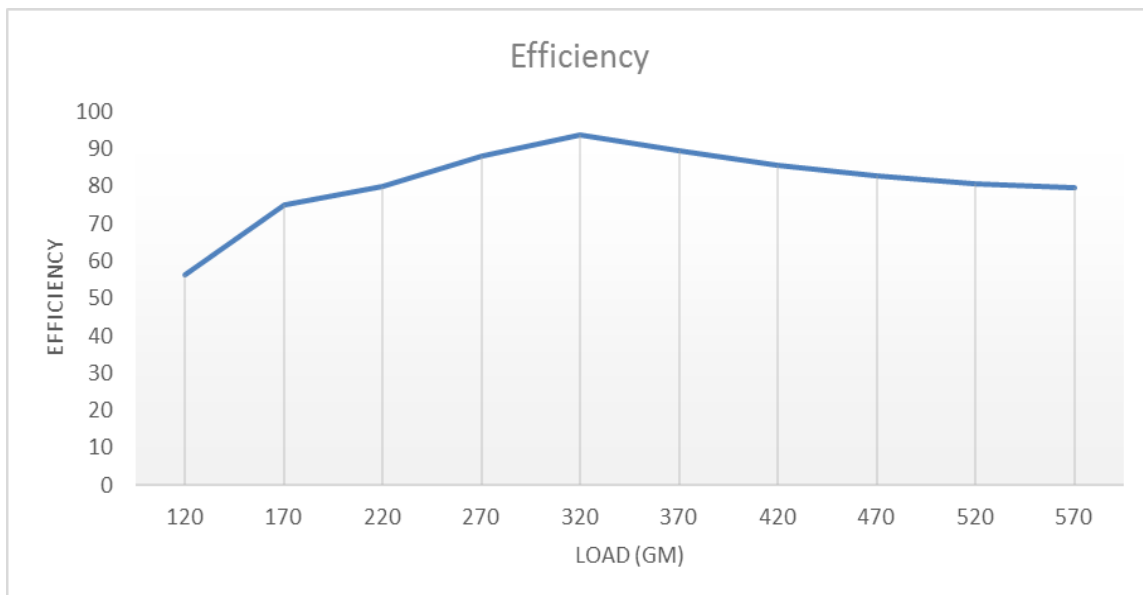


Fig. 7: Graph of efficiency Vs load

Figure shows the comparison of efficiency with load. It shows that efficiency increases with increase in load with maximum value of 93% at 320 gm load.

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V. EFFICIENCY

The mechanical design efficiency of the EclipseGearbox results in significantly greater efficiency than traditional planetary gearboxes, due to the reduced number of energy dissipating components and to the fact that energy travels through only one set of gears and bearings. There are two primary components that dissipate energy in a gearbox system: the gear tooth contact and the bearing contact. A basic rule of thumb in gearbox design for energy loss through gear tooth contact is approximately one half of one percent (1/2 of 1%) for every stage of gear interaction that the energy passes through. Bearing contacts contribute energy loss through rolling motion. The linkage bearings in the Eclipse are small in size in relation to traditional gearbox bearings and rotate back and forth about 15 degrees, producing only minimal energy losses. Only the crankshaft bearings rotate a complete 360 degrees and are similarly relatively small in size. Traditional gearbox systems routinely suffer energy losses amounting to four to five percent (4 – 5%) due to multiple stage planetary gear sets and massive bearings. The Eclipse gearbox will operate with a total mechanical efficiency of approximately 95 percent. Until this claim is validated by testing, a conservative estimate would be a mechanical efficiency no less than 85 percent.

VI. ENDURANCE LIFE, SIZE AND WEIGHT

The long endurance life, small size and lightweight are the primary strengths of the Eclipse Gearbox. Its size is equivalent to a traditional gearbox with half the weight. Even with half the weight, the EclipseGearbox handles greater torque loads with gears and bearings selected to handle all the requirements of the most challenging wind turbine applications, while maintaining endurance over a greater length of time. Gear tooth contact stress is substantially lower due to the increase in the number of gear teeth that are simultaneously engaged. The decreased tooth contact stress directly increases the endurance life and torque capacity of the gears.

VII. CONCLUSIONS

This work has presented a powerful method of enhancement of windmill applications by designing multistage linkage based eclipse gearbox. Performance of windmill increases as well as the power and efficiency is also increases.

- The torque increases with the increase in the load. With increase in load speed decreases means torque increases with decrease in speed.
- Output power indicates a rising trend up to 320 gm load and then slightly drops with further increase in load. The maximum power is obtained at 320gm load and 1250 rpm speed.
- Efficiency increases with increase in load up to certain limit and after that efficiency decreases with further increase in load. The maximum efficiency of about 93 percentage is obtained at 1250 rpm speed.
- All of these advantages combined with long endurance life and optimal efficiency, dramatically lower wind turbine operating expenses and solve the gearbox reliability problem.

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