

Wind Turbine Tribology

Wind turbines convert kinetic energy of the wind into electrical energy. In 2015, wind power avoided over 637 million tons of CO₂ emissions globally. In the same year, annual installations crossed the 60 GW mark for the first time in the history.

The estimated life of wind turbines is about 20 years, but the failure rate of wind turbines is about three times higher than that of conventional generators. The operating and maintenance costs of wind turbines have to be minimised. Failure of mechanical or electrical parts is also a factor. Hence reduction in downtime requires good condition monitoring along with excellent tribological design of internal and external parts. A wind turbine consists of complex mechanical parts. Companies invest a lot in research and development, design and construction of wind turbines to avoid heavy and frequent maintenance costs.

Mainshaft bearings

Between the rotor and the generator, the main shaft incorporates spherical roller bearings which experience micropitting caused by varying loads, developed from high- and intermediate-speed stages on sliding contact between the rolling elements and the bearings.

Micropitting results in material loss which leads to concentration of stress at certain points, which can initiate raceway fatigue. This can bring about bearing failure.

Replacing spherical roller bearings with preloaded tapered roller bearings and proper use of grease and application of coatings can improve bearing life.

Gearbox

The gearbox connects the low speed shaft to the high speed shaft and increases the rotational speed to an rpm that is commonly required by generators to produce electricity. The gearbox is the heaviest and costliest component of the entire wind turbine. During periods when the wind is not driving the rotor, small-amplitude vibrations can lead to fretting wear of the gearbox components.

The gears of a wind turbine system are subjected to both rolling and sliding contact under varying load. The primary failure modes in wind turbine gears are generally scuffing, pitting, and abrasive wear. In order to prevent wear damage to the gear teeth, the gears are typically lubricated using oil or are protected via various surface treatments.

Gear oil contamination due to debris, entered during manufacturing or internally generated, can deteriorate the film formation capability of the lubricant. Debris travelling with lubricant flow can damage the surface of gearbox components via erosive wear. Proper filtration of the gearbox oil should be incorporated in order to keep the oil debris free.

Fog, rain and snow can introduce water contamination of gearbox components. Water contamination can significantly degrade the gearbox lubricant and can also cause the formation of rust on internal components. Proper sealing

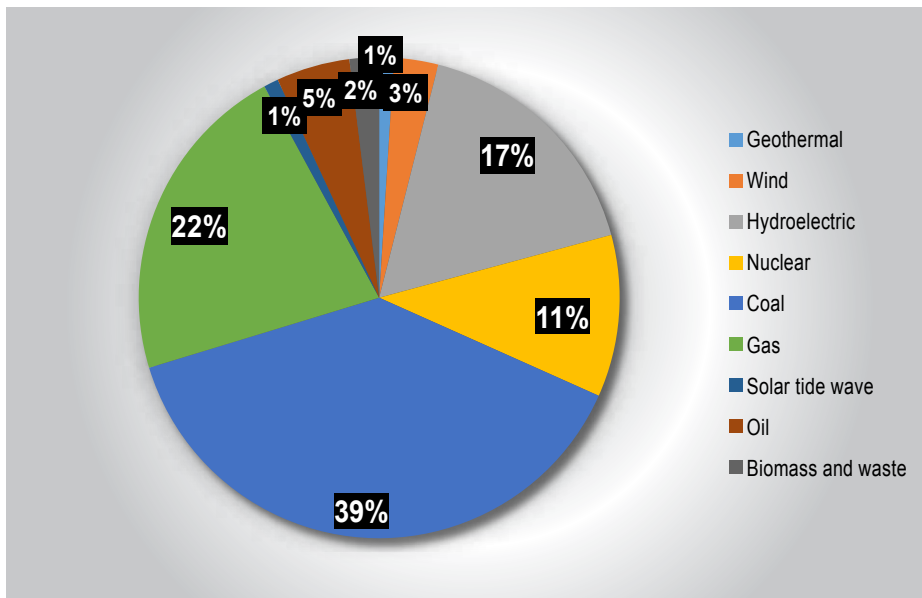


Figure 1. World electricity production from all energy sources in 2014

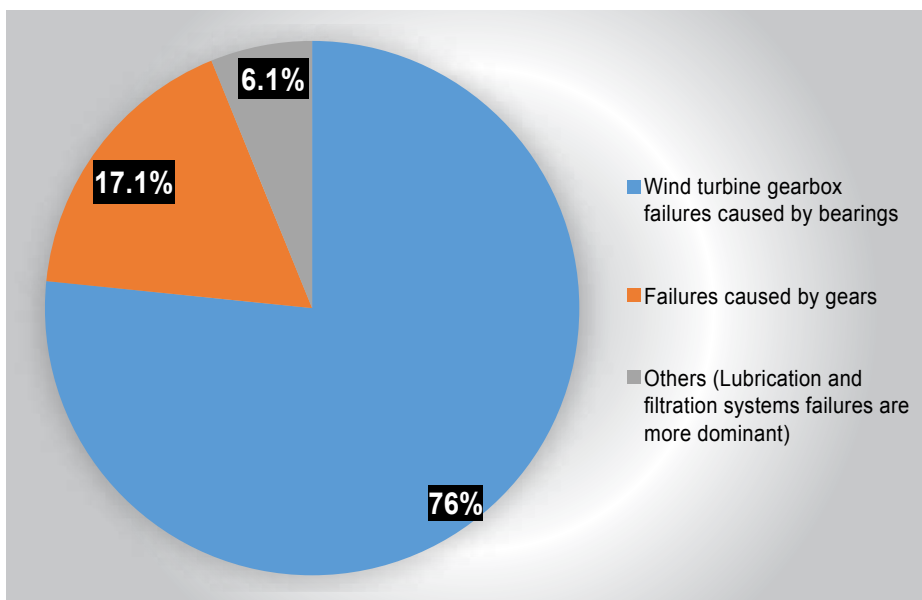


Figure 2. Wind turbine component failure percentage in U.S



of the gearbox can prevent water from entering into the gearbox.

White structure flaking (WSF) or white etching crack (WEC) can bring about premature failure of roller bearings in wind turbine gear boxes. This type of flaking is induced by diffusing of hydrogen from the lubricant into the steel, causing the steel to embrittle. White structure flaking life can be improved by use of black oxide coatings and by optimisation of alloy elements in steel and heat treatments selection at the time of manufacturing.

Wind turbine tower

Wind turbines are often installed in seas or oceans as the flow of wind is more continuous and speedy than on land. The towers of these wind turbine are fixed inside water via huge clamps and concrete blocks. A high proportion of this tower's length is in contact with the sea water. Corrosion of tower due to salt water, biofouling and mechanical loads due to floating ice can greatly impact the strength of the tower. Use of corrosion resistant materials and coating systems can be used to resolve this issue.

Wind turbine blades

Tribocorrosion of blades and icing on blades can cause increased drag. Again anti-corrosion coatings, good blade design and use of deicing systems would be useful.

Pitch and yaw bearings: The pitch system adjusts the blade angle relative to the wind flow. The yaw system serves to orient the blades in the direction of the wind. Pitch and yaw bearings are typically an eight-point contact ball bearing which is case hardened and heat treated to improve strength and properties.

The tribological issues related to pitch and yaw bearings are false brinelling, fretting, corrosion and friction. False brinelling and fretting can be prevented by reducing vibration inside the system and by using proper lubricant. Countermeasures for corrosion involve anti-corrosion treatments and good lubrication practices.

Frictional issues can be resolved by proper tribological design. The bearings should be designed in a way that they are able to withstand and distribute all kinds of loads whether they are static or dynamic.

Mechanical brake

A wind turbine mechanical brake is a disc brake located on the small fast shaft between the gearbox and the generator. The brake is generally used when

the wind turbine is being repaired to ensure safety of maintenance staff.

Braking loads, loss of brake oil, corrosion are some of the factors influencing performance and reliability of these brakes. Condition monitoring and better tribological designs can help improve durability and lifetime of these brakes.

Generator

A generator comes last in the chain of internal components and produces current that can be stored or used directly for powering industries or homes. Improper insulation of these generators can cause the passage of current through bearings resulting in small burnt pits on the bearing surface. This kind of arcing damage can be prevented by using ceramic bearings and proper insulation.

Micro-organisms such as bacteria, yeasts and algae can develop inside lubricants if they encounter desired growing conditions such as water, optimum temperature, organic materials and oxidative particles

Wind turbine oil contamination

Oil generally serving as a lubrication source, if not maintained properly can also become a source of failure of wind turbine components. Oil degradation mainly includes loss of additives, oil oxidation and microbial growth.

Loss of oil additives or additive drop out occurs when additives present in the oil have a strong affinity for water. These additive molecules form bonds with water molecules and contaminate the whole lubrication system.

Oil oxidation is one of the most severe forms where oxygen atoms chemically react with oil molecules and produce acids and polymeric compounds as by-products. These acids promote corrosion of various parts of the wind turbine.

Micro-organisms such as bacteria, yeasts and algae can develop inside lubricants if they encounter desired growing conditions such as water, optimum temperature, organic materials and oxidative particles. The organisms can quickly deplete oil quality and performance. Installation of high quality oil filtration systems and air breathers, frequent lube analysis, use of biocide are some ways to avoid contamination issues.

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