Why Wind Turbine Gearboxes Fail

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Despite great efforts to improve the wind turbine gearbox designs, analysis, manufacturing, lubrication systems, control systems, etc., wind farm operators still suffer costly gearbox repairs and replacements multiple times in the life of their wind turbines. Why?

The NREL Gearbox Reliability Collaborative has answered some of the key "whys" to this question. "Most gearbox failures do not begin as gear failures or gear-tooth design deficiencies. The observed failures appear to initiate at several specific bearing locations under certain conditions, which may later advance into the gear teeth as bearing debris and excess clearances cause surface wear and misalignments." [1]

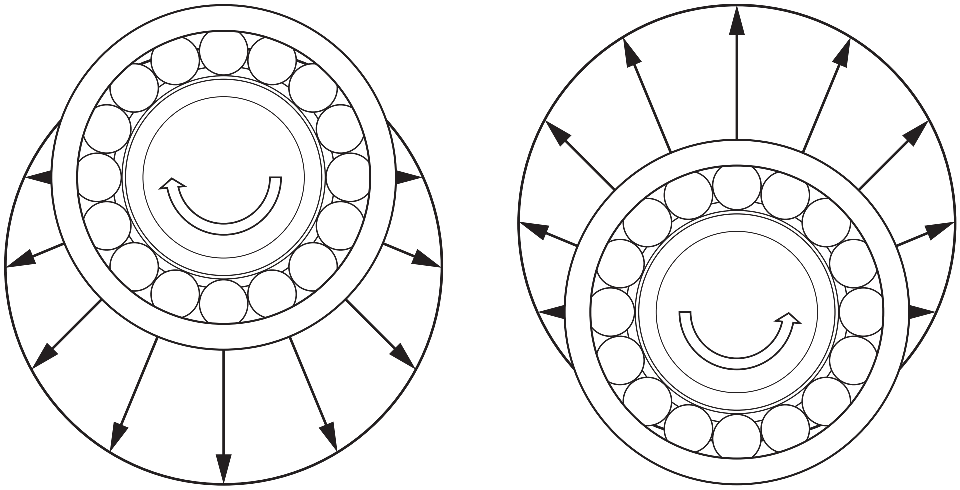
Bearing experts agree that the deterioration of the rollers generally starts with micropitting, also called 'grey staining' or 'frosting'. This consists of microscopic cracks only a few microns deep (about .0001 inches). Individually these cracks are too small to be visible. As they accumulate they appear as grey stains on the roller surface. Eventually the bearing roller starts to shed its cracked and weakened surface losing a small bit of its precision tolerance. Furthermore, this contaminates the oil with microscopic super hard steel particles most of which are too small to be filtered out. Why does grey staining begin? Typically it is a breakdown of the oil film that separates the rollers from the races.

Bearing rollers showing pitting and spalling damage.

Why do the rolling elements of the bearing break through the oil film and contact the races?

Even in a properly designed and lubricated gearbox, oil film breakdown can occur during transient events that can cause concentrated loading and skidding of the bearing rollers on the races.

Instrumentation on wind turbine gearboxes have measured the movement of gears, shafts, and even the rollers of the bearings to find the root cause. The data shows the gears and shafts shifted rapidly, and the bearing rollers are skewed during transient torsional reversals in the drive system. The load zone of the bearing shifts almost 180 degrees. Concentrated edge loading on the skewed rollers can break through the oil film. Slower unloaded rollers must accelerate rapidly as they suddenly become loaded, causing skidding that magnifies the surface stress on the skewed rollers. In some bearing locations the load zone may simultaneously shifts axially 180 degrees, adding axial skidding and impact loading to the overstressed rollers.



Why are wind turbine drive systems subject to torsional reversals?

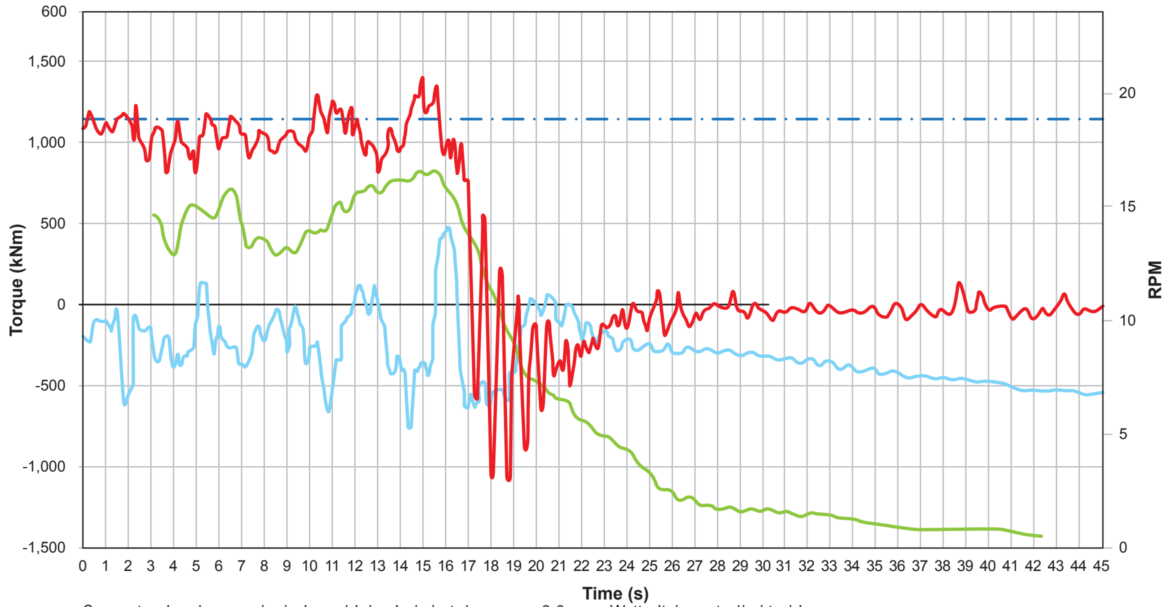
There are many potential transient load events in their operation that can cause the drive system to rapidly go through a torsional reversal. Such events can include:

- *Grid loss*
- *Grid faults*
- *High wind shutdowns*
- *Wind gusts*
- *Curtailments*
- *Other Emergency stops*
- *Generator short circuits*
- *Resonant vibration*
- *Control malfunctions*
- *Crowbar events*

Although these torsional reversals are infrequent, they can be very severe. Older type stall controlled two speed wind turbines with blade tip braking are subject to these same infrequent severe torque reversals. In addition they see reversals during normal blade tip braking, contactor engagements, and downshifting.

Why can’t controls protect the gearbox from torsional reversals?

Wind turbines have large rotating masses in the blades and generator that are subject to a variety of transient loads. Trying to use controls alone to ensure against all the potential causes of torsional reversals would be difficult and expensive.

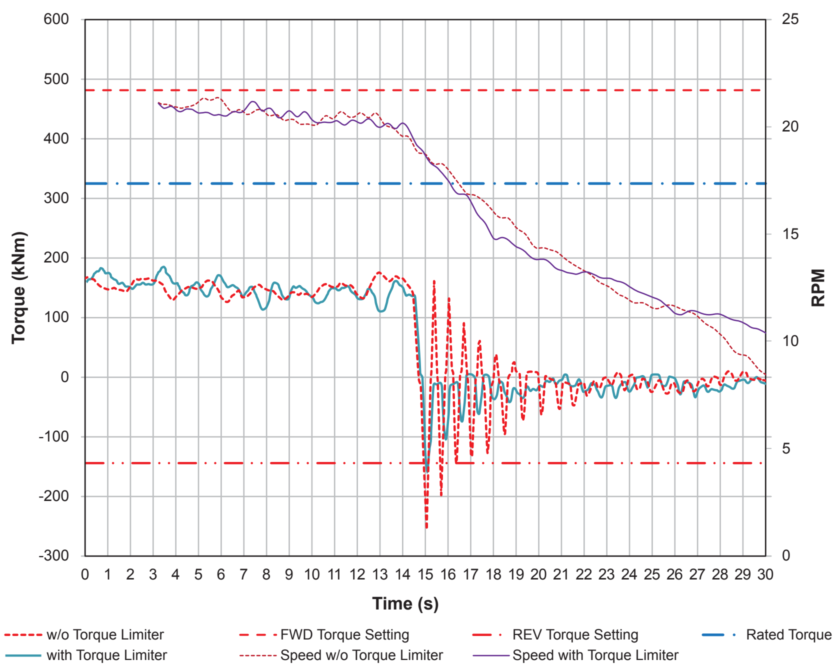


Severe torsional reversals during a high wind shut down on a 2.0 megaWatt pitch controlled turbine.
(Measured utilizing AeroTorque’s WindTM™ torque monitoring system.)

Don’t torque limiters prevent damage during torsional reversals?

Common torque limiters set at 150% to 180% of the wind turbine’s rated torque do provide some protection against severe forward torque spikes (where the bearing rollers are in position to take the load). However, that same slip torque level in reverse is high enough to damage the skewed and skidding rollers during sudden torque reversals.

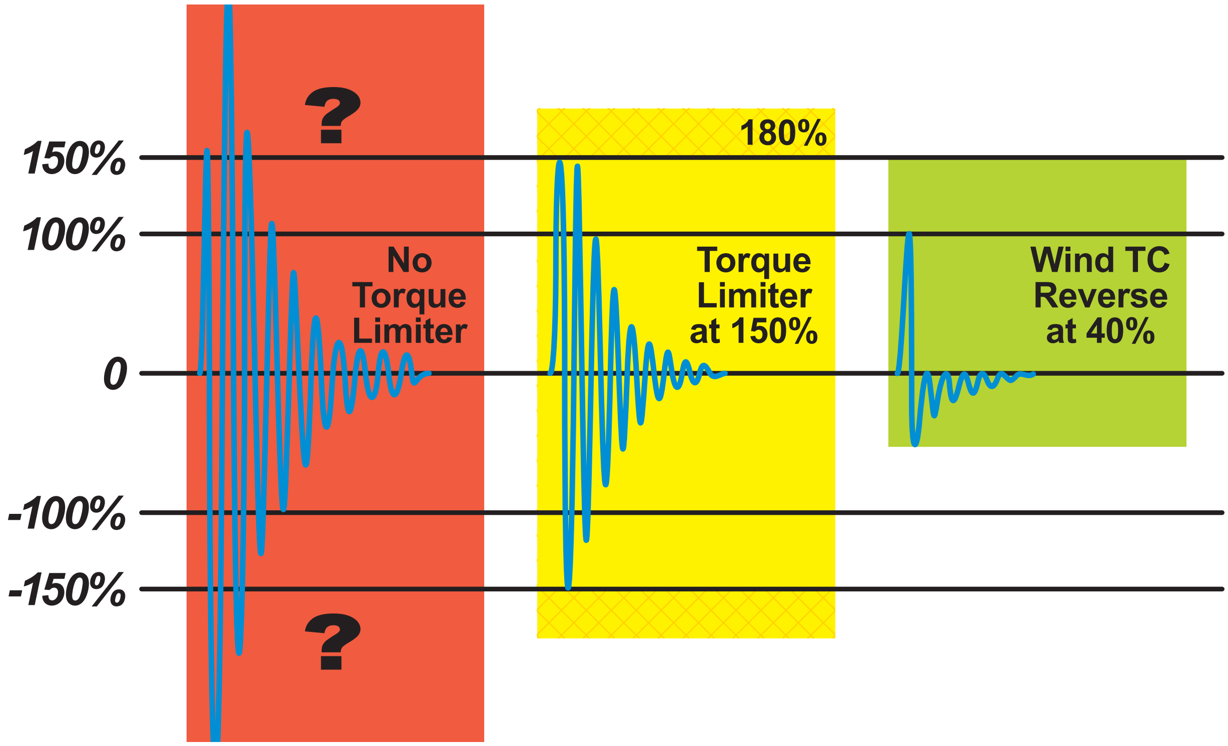
AeroTorque has developed the WindTC™ Torsional Control product with the ability to set the reverse slip torque much lower than forward.



Two nearby wind turbines during a torque reversal event. One equipped with AeroTorque WindTC (blue line) and the other without (red line)

Prolonging life of the entire wind turbine drive system

The AeroTorque WindTC™ retrofitted onto the generator shaft can prolong gearbox life and can benefit the entire drive system from the fibers in the rotor blades to the winding insulation in the generator rotor. By controlling the levels of reverse torque stress, the fatigue life of all the drive system components can be extended. See chart below. Even in modern pitch controlled turbines there is a growing awareness of a link between emergency stops frequency and the life of gearboxes and blades. The WindTC™ with its unique ability to set the reverse torque lower than the forward torque provides a simple, lean, economical retrofit solution to transient torsional reversals. It has a potential to significantly improve the ROI of todays and tomorrows wind farms.



Comparison of maximum forward and reverse torque loads that a turbine drive system can be subject to – no torque limiter vs. conventional torque limiter vs. WindTC

Footnote:
[1] Improving Wind Turbine Gearbox Reliability Conference Paper, NREL/CP-500-51548, May 2007, from the National Renewable Energy Lab, authored by Walt Musial, Sandy Butterfield, and Brian McNiff

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