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New lubrication device to minimize wear at the pitch gear

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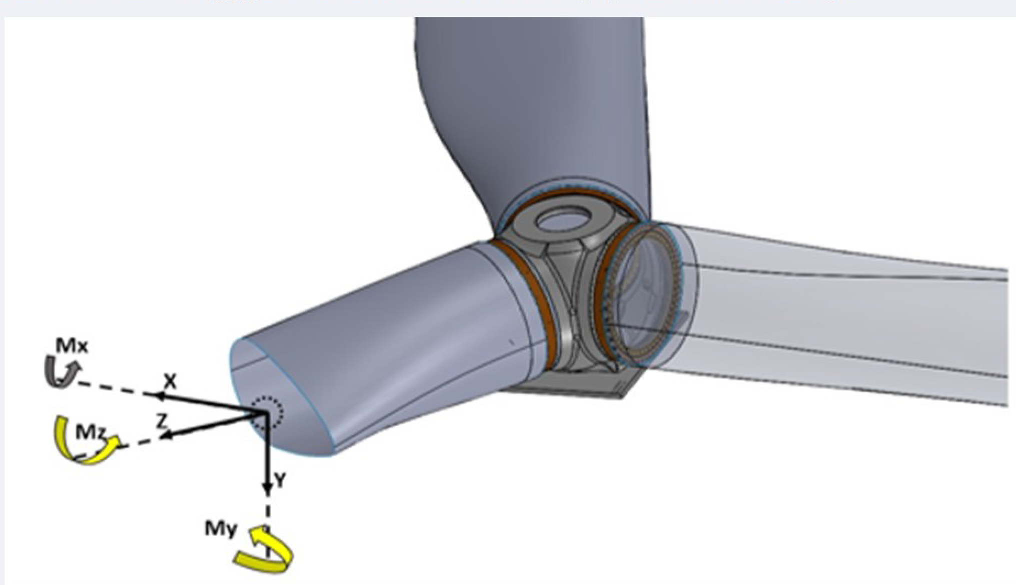
Abstract

At low wind speeds the pitch system works at the 0º position without movement. When the wind turbine approaches its nominal power, the pitch system starts to actuate inducing oscillations into the system due to the **continuous movement of the pitch** due to the thrust and the wind speed changes. The dynamic operation during long periods in the same position **reduces the lubricant thickness** between the teeth and consequently causes direct contact between the two metal surfaces. This factor together with the lower crown surface hardness causes **excessive wear** as defined ANSI/AGMA 1010-E95 in the zero position as reports Holierhoek [1].
Patented solutions to minimize the gear wear at specific points like the 0º pitch position exist. The proposed solutions essentially tune parameters such as surface state [2-3], stress, mechanical contact [4] and tribology [5-7]. However, the solutions presented in [2-3] cannot eliminate the preventive maintenance, while the solutions in [4-5] require expensive parts such as another pinion and a compressor. The solution in [6] **requires programed stops of the turbine which cause generation losses**, and the solution in [7] is difficult to integrate in ongoing wind turbines due to the necessity of pinion replacement.
In spite of these issues, the most used solution is the lubrication pinion presented in [6], therefore the new lubrication device called **MiCRoLuBGeaR** is a complement that can avoid the lubrication programed stops and consequently **increase the electricity generation and reduce wear**.

Objectives

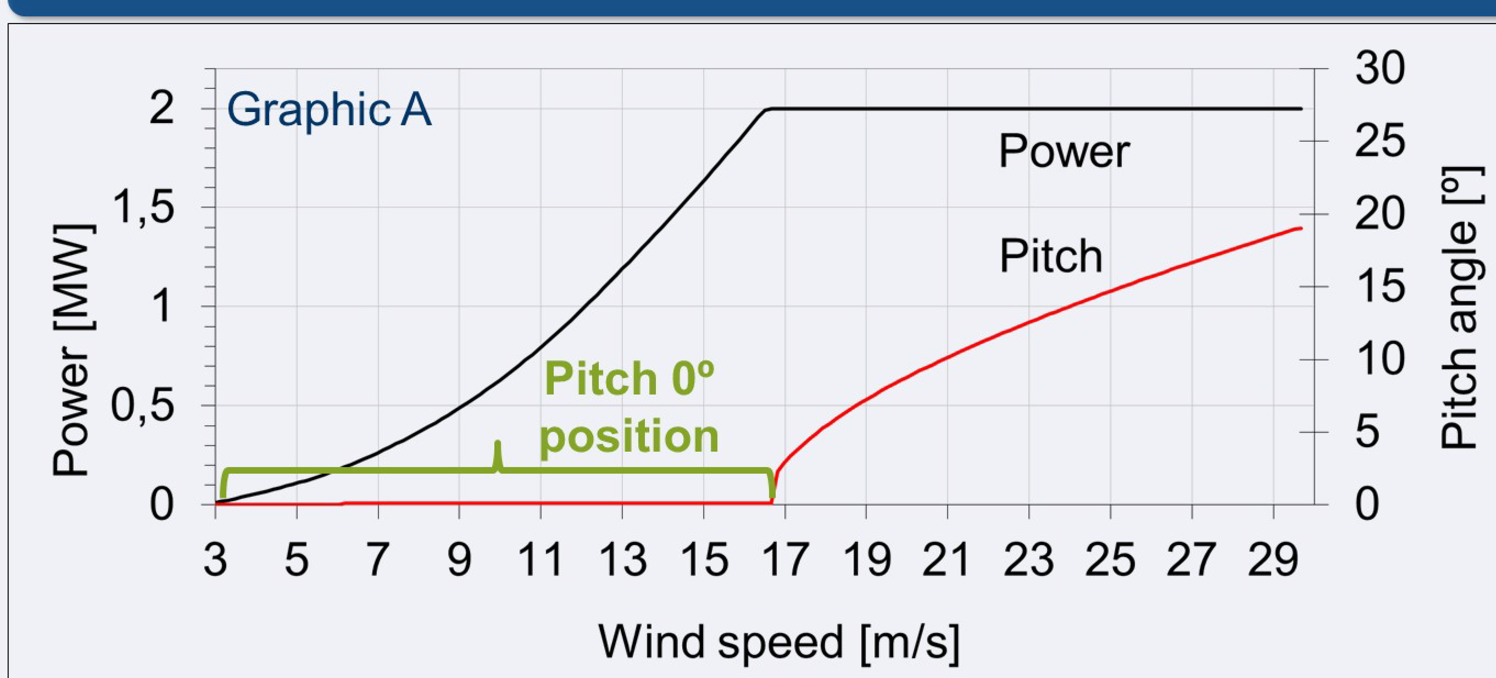
To manufacture the **new MiCRoLuBGeaR** devices micro-fabrication technology is used. The main challenge in theses dimensions is the control of the grease flow dynamics in dimensions smaller than 1 mm, which has not been previously studied. Our previous studies [8] showed that the device has an appropriate performance for gear modules up to 12, commonly used at wind turbines of 2 MW. The dedendum free space increases as the gear module increases, so the device will be useful for wind turbines bigger than 2 MW approximately.



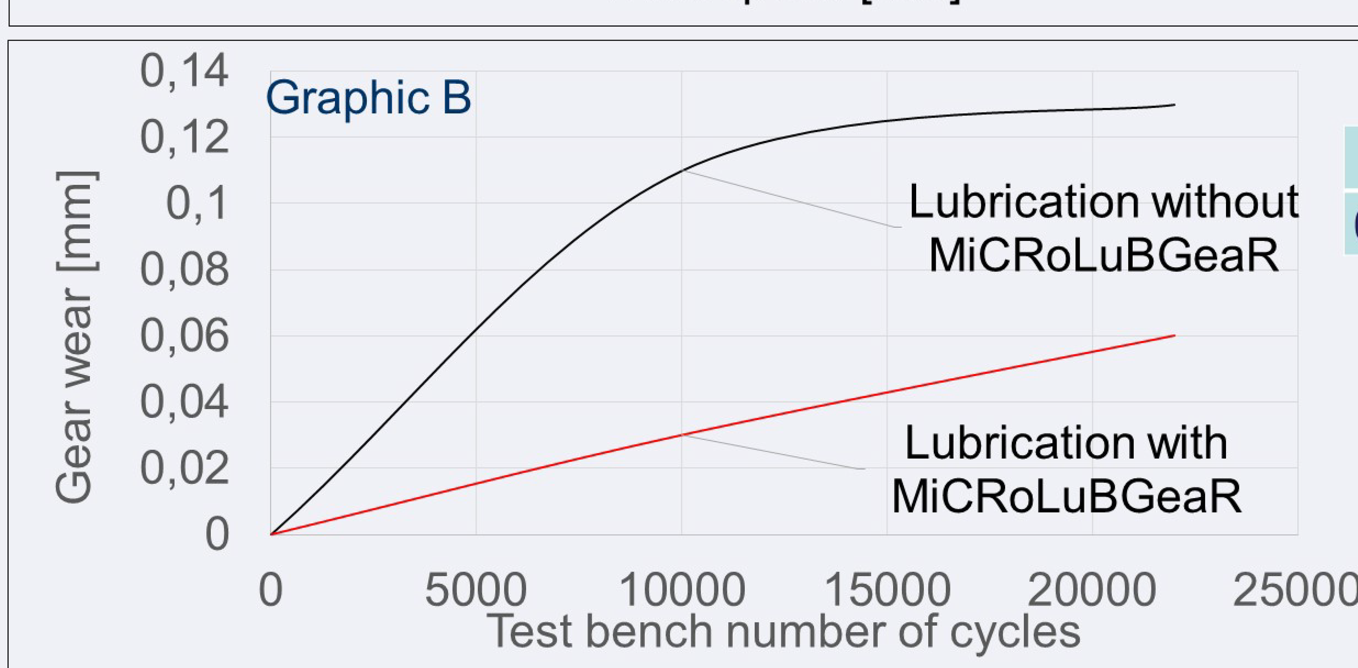
Therefore, to validate **MiCRoLuBGeaR** device Micro Particle Image Velocimetry (μPIV) is used to analyze the flow behavior of a NLGI grade 1 and 2 greases in channels that can be integrated in a 12-module gear. Samples of the injected grease were collected to verify that grease had not degraded during flow in the micro-channel. Furthermore the influence of the temperature on the device behavior is validated at temperatures from -20ºC using greases NLGI grade 1 and 2, useful for wind turbines that operate under cold climate conditions.
The μPIV results and the cold climate operation behavior are used to define the integration of the lubrication device in the wind turbine lubrication circuit and to define a lubrication strategy to inject fresh grease at the pitch zero degree position.
A novel test bench is built to reproduce the phenomena of the excessive wear at the 0º position of the pitch. The main factors needed to reproduce the excessive wear due to the wind turbine dynamic operation in the test bench are:

- The blade micro movements caused by the gearbox backlash and the torque caused by the aerodynamic forces of the blade to turn around its axis. To simulate this, a constant torque M_z [9] is preassembled to the blade and a 0.034º oscillation (0.5 mm of backlash in the crown of M12 and Z139) is applied through an electric motor.
- The stress cycle traction and the compression on the blade when the pitch works in the 0º position. This is simulated in the test bench by M_x and M_y at 0.3 Hz to simulate the blade revolution in operation.

Methods

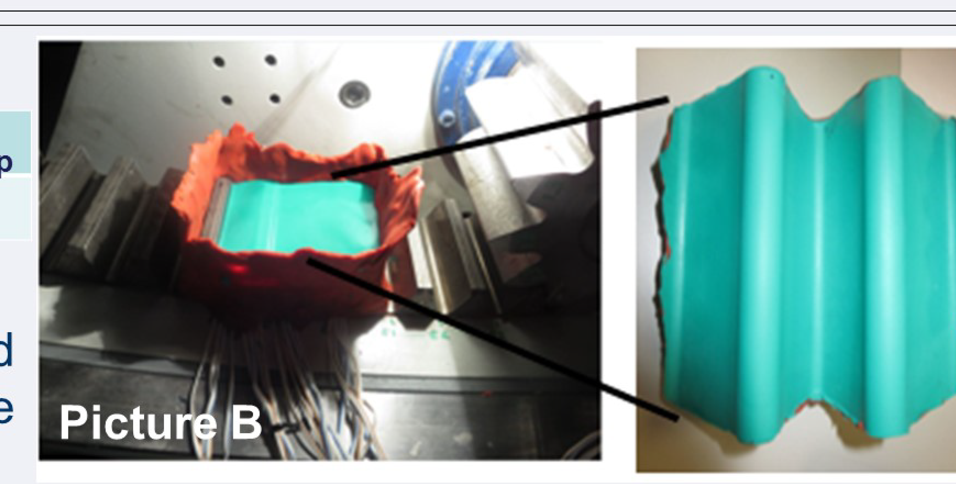


The graphic A shows the pitch operation at zero degree position for low velocities where the wind turbine operates an average of 60% of the time. For this reason it is required programmed stops to lubricate the teeth. The picture A shows MiCRoLuBGeaR installed to lubricate the tooth under operation to avoid programed stops and consequently increase energy generation.



TEST BENCH LOADS

Backlash	M_z/ $M_{torsion}$	M_x/ M_{edge} and M_y/ M_{flap}
0.5mm at 0.2Hz	Constant ±40KNm	2000 kNm at 0.3Hz



A test bench validation of 2MW pitch bearing was performed with the loads defined in the previous table. To quantify the evolution of the teeth wear, teeth molds was obtained at different test bench cycles as picture B shows. The wear evolution it is represented in the graphic B showing a lineal wear evolution until the wear starts at the adjacent tooth and consequently it is reduced. The wear using MiCRoLuBGeaR it is reduced more than 70%.

Conclusions

This study demonstrates **MiCRoLuBGeaR** can properly lubricate pitch teeth at zero degree position and **reduce gear wear up to 70%** respect to current technologies while the wind turbine operates. The technology is **easy to implement in all ongoing** wind turbines and the current automatic lubrication systems. Additionally MiCRoLuBGeaR can operate **in environments of cold condition until -20ºC**. These characteristics improve the low efficiency of current lubrication systems that generates energy generation losses. Furthermore, these losses will increase in future wind turbines; this novel technology is a key element in the contribution to make the new multi megawatt **wind turbines more profitable**. The technology presented also becomes essential in offshore wind turbines where the maintenance reduction is of high importance.

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