Corrigendum

Corrigendum: Correlation of Planetary Bearing Outer Ring Creep and Gear Load Distribution in a Full-Size Wind Turbine (J. Phys.: Conf. Ser. 1452 012062)

Felix M. Schlüter, Georg Jacobs, Dennis Bosse, Thilo Brügge, Felix Schlegel
Center for Wind Power Drives, RWTH Aachen University, Germany
Email: felix.schlueter@cwd.rwth-aachen.de

Description of this corrigendum
After publication of this paper, the authors found out that the evaluation of bearing ring creep was carried out with an inverted sign in the code of the automated evaluation script. Therefore, all figures showing bearing ring creep have been inverted for this corrigendum and the interpretations of the figures have been adapted accordingly.

Also, after repeated thorough checking of “figure 2” (definition of roller-induced creep and gear creep), it was decided to edit the figure to make the definition unambiguous.

For improved reading, the corrected full-paper including all changes from this corrigendum can be accessed through the doi: 10.18154/RWTH-2020-12362

Page 1
In the “Abstract” section, the following text appears:
“In this work, bearing outer ring creep in the planetary gear of a wind turbine gearbox is investigated. So far, gear creep has only been investigated experimentally on very small bearings under simplified load conditions. This paper presents experimental measurement results from a full-size 2.75 MW wind turbine. The test were performed on a system test bench capable of applying loads in all six degrees of freedom at the rotor hub.”

This should read:
“In this work, bearing outer ring creep in the planetary gear of a wind turbine gearbox is investigated. So far, gear creep has only been investigated experimentally on very small bearings under simplified load conditions. This paper presents experimental measurement results from a full-size 2.75 MW wind turbine. The tests were performed on a system test bench capable of applying loads in all six degrees of freedom at the rotor hub.”

Also in the “Abstract” section, the following text appears:
“Key findings are that outer ring creep speed increases with global rotational speed and torque. Also, gear creep – acting in the opposite direction of roller-induced creep – was found at the generator-sided bearing ring for loads below 40% nominal torque.”

This should read:
“Key findings are that outer ring creep speed increases with global rotational speed and torque. Also, roller-induced creep was found at the generator-sided ring bearing for 40% and 60% nominal torque. At high torque, both bearing rings show gear creep only.”
Pages 2 and 3
In the “Literature overview bearing creep – 2.1 Roller-induced creep” section, the following text appears:
“Roller-induced creep refers to a mechanism that leads to small, irreversible tangential movement of a bearing ring in/on its seat.”

This should read:
“Roller-induced creep refers to a mechanism that leads to small, irreversible tangential movement of a bearing ring relative to its seat. This occurs in the rotational direction of the entire rolling element set relative to the bearing ring. See figure 2: the roller set is rotating clockwise relative to the bearing ring and the creep of the bearing ring is following that movement.”

In the “Literature overview bearing creep – 2.2 Gear creep” section, the following text and figure (2) appear:
“In addition to roller-induced creep, gear creep can occur if the bearing housing is a gear. The radial and tangential load situation in each gear tooth engagement and the resulting tooth bending lead to the formation of an additional gap in the area of each teeth engagement. When set in rotation, this gap is set into motion as well. Other than roller-induced creep, gear creep drives the bearing ring against the rotational direction of the rolling element set. Figure 2 shows the rotational direction of the bearing ring (red dot) relative to the gear wheel (blue dot) for roller-induced creep (middle) and gear creep (right). The rotational direction of the rolling element set (black dot) is the same in all pictograms.”

The text should read:
“In addition to roller-induced creep, gear creep can occur if the bearing housing is a gear. The radial and tangential load situation in each gear tooth engagement and the resulting tooth bending lead to the formation of an additional gap in the area of each teeth engagement. When set in rotation, this gap is set into motion as well. As opposed to roller-induced creep, gear creep drives the bearing ring against the rotational direction of the rolling element set relative to its housing. Figure 2 shows the rotational direction of the bearing ring (red dot) relative to the gear wheel (blue dot) for roller-induced creep (top right) and gear creep (bottom right). The rotational direction of the planetary gear wheel and the rolling element set (black dot) is the same in all pictograms.”
And the figure (2) should be replaced by:

Also in the “Literature overview bearing creep – 2.2 Gear creep” section, the following text appears:
“In this case, tangential gear creep is more likely to be seen at the bearing (rotor- or generator sided bearing) where the “pre-loadzone” tooth engagement ends due to the gear’s helix angle and direction of rotation. For this, the “pre-loadzone” tooth engagement is defined the one that a tooth passes through before rotating into the bearing load zone.”

This should read:
“According to [5], tangential gear creep in this case is more likely to be seen at the bearing (rotor- or generator sided bearing) where the “pre-loadzone” tooth engagement ends due to the gear’s helix angle and direction of rotation. For this, the “pre-loadzone” tooth engagement is defined as the one that a tooth passes through before rotating into the bearing load zone.”
Page 5
In the “Test setup and experiments” section, the following text appears:
“When no creep occurs, the time difference between a “planet gear peak” and an “outer ring peak”
(Δt₁) remains constant over time. If the time difference changes (Δt₂), tangential creep occurred. In the
shown example Δt₂ > Δt₁ which means that the bearing ring took more time for one revolution than the
planet gear. Hence, the bearing ring is performing a relative rotation in the planet gear against the
direction of rotation which would be interpreted as gear creep. As Δt₁ > Δt₂ the creep speed increased,
for example due to increased load.”

This should read:
“When no creep occurs, the time difference between a “planet gear peak” and an “outer ring peak”
(Δt₁) remains constant over time. If the time difference changes (Δt₂), tangential creep occurred. In the
shown example Δt₂ > Δt₁ which means that the bearing ring took more time for one revolution than the
planet gear. Hence, the bearing ring is performing a relative rotation in the roller set’s direction of rotation
relative to the planet gear. Therefore, this movement is defined as roller-induced creep. As Δt₁ > Δt₂,
creep is still present in this time range.”
In the “Results – 4.1 Constant operating points” section, the following figures (11 and 12) and text appear:

The figure (11) should be replaced by:

“The data clearly shows higher creeping for higher torque. Also, all curves show a linear behavior. Therefore, the creeping appears to be constant over time. For the rotor-sided bearing, only roller-induced creep was found. However, the generator-sided bearing shows negative tangential creep for 40% and 60% nominal rotor torque and therefore gear creep. This result correlates with information from literature as the generator sided bearing is where the gear engagement with the sun gear ends before entering the bearing load zone as described in chapter 2.2. At 100% load the rotor-sided bearing shows almost twice as much positive creep as the generator-sided bearing which is partially “held back” by the still ongoing, but overcompensated gear creep.”
This should read:

“The data clearly shows higher creeping for higher torque. Also, all curves show a linear behavior. Therefore, the creeping appears to be constant over time. For the rotor-sided bearing, only gear creep was found. However, the generator-sided bearing shows positive tangential creep for 40% and 60% nominal rotor torque and therefore roller-induced creep. This behavior does not correlate with literature [5] as the “pre–loadzone” tooth engagement ends on the generator side, but the rotor-sided bearing ring clearly shows more gear creep than the generator-sided bearing ring. At 100% load the rotor-sided bearing shows almost twice as much gear creep as the generator-sided bearing which is partially “held back” by the still ongoing, but overcompensated roller-induced creep.”

The figure (12) should be replaced by:
In the “Results – 4.1 Torque ramps at constant speeds” section, the following figure (13) and text appear:

The figure (13) should be replaced by:

“A The curves of the generator-sided bearing also qualitatively show the expected behavior: gear creep at lower loads, roller-induced creep at higher loads and an increase of creep with increasing rotational speed.”

This should read:

“The rotor-sided bearing ring shows gear creep over the entire torque range and an increase in creep speed with rotational speed and torque. The generator-sided bearing ring shows roller-induced creep at lower loads, gear creep at higher loads and an increase of creep speed with rotational speed and torque.”
In the “Results – 4.3 Loads in 6 degrees of freedom –6DOF” section, the following figure (15) appears:

The figure (15) should be replaced by:
Page 10
In the “Conclusion and Outlook” section, the following text appears:

“For selected load cases, outer ring creep was evaluated. A clear dependency on rotor torque was shown for both bearings’ outer rings with 100% nominal rotor torque leading to about 1.8° and 40% nominal torque leading to only 0.4° of creep at the rotor-sided bearing. Gear creep – leading to tangential movements in the opposite direction of roller-induced creep – was found at the generator-sided bearing’s outer ring for 60% and even more for 40% nominal rotor torque.”

This should read:

“For selected load cases, outer ring creep was evaluated. A clear dependency on rotor torque was shown for both bearings’ outer rings with 100% nominal rotor torque leading to about 1.8° and 40% nominal torque leading to only 0.4° of negative defined gear creep at the rotor-sided bearing. Roller-induced creep – leading to tangential movements in the opposite direction of gear creep – was found only at the generator-sided bearing’s outer ring for 40% and 60% nominal rotor torque. At higher torque, the generator-sided bearing ring also showed increasing gear creep.”