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Considerations for Increasing the Durability of the Main Shafts Bearings of Wind Turbine

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1. INTRODUCTION

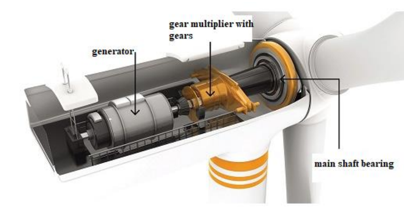
The novelty in this work consists in the identification of constructive solutions for bearing the main shaft with mounting in three and four support points. Improvements to the existing bearing construction solutions for existing turbines are also presented. As the bearings perform their function, which is essential to the mission inside the current turbines, with MW installed powers, dynamic stresses and unpredictable stresses lead to costly premature repairs. For the benefit of the wind industry, the reliability of the main shaft bearings needs to be improved. [1], [2], [3] The market demand motivates the development of new technical solutions for the replacement of standard radial thrust roller bearings in three-point bearing turbines, such as wear-resistant radial roller bearing roller bearings and two-row radial tapered roller bearings, pre-stressed [4]. For this reason, this work presents some constructive solutions that are efficient in the wind turbine industry. Also, there are presented some mode of failures, like: the incipient stages of micro exfoliation of the working surfaces of a two-row radial roller oscillating roller bearing in the main shaft of a wind turbine, insufficient lubrication, the simulations of different stages of distributions of pressure on inner and outer rings, equivalent (von Mises) stresses and an another improved construction solution of bearings.[4] In conclusion, the criteria for choosing the types of reliable wind turbines imply a special attention in choosing reliable bearing elements, with long operation times and as few repair / maintenance costs as possible. [5], [6]

1.1.The constructive solutions of bearings in the wind turbine industry

Three-point bearing bearing construction of the main shaft

In the three-point bearing construction, the main shaft is supported by the torsion arms of the gear multiplier with gears and a single oscillating radial bearing with two-row barrel rollers in front of the gear multiplier. This arrangement allows:

- a shorter nacelle and a reduced mass of the wind turbine;
- greater deformation and misalignment in the wind turbine drive chain elements.



Four-point bearing construction of the main shaft

In the four-point bearing bearing (Figure 1b), the main shaft is supported by the torsion arms of the gear multiplier and two main bearings in front of the gear multiplier. These main bearings are often oscillating radial bearings with two-row barrel rollers, but other constructive arrangements, including cylindrical and tapered roller bearings, are commonly used. This arrangement allows:a) a longer platform and a larger wind turbine mass; b)a higher rigidity of the kinematic system;c) a much reduced deformation and misalignment in the elements of the kinematic transmission chain of the wind turbine.

1.2. Motivation for choosing study bearings wind turbine solutions:

The use of a single two-row radial oscillating barrel roller bearing as the main shaft bearing in wind turbines with power has changed - although in the past it was the preferred construction solution, now operators are looking for a better solution. [2] The main reason is the premature failure observed in this type of bearings, especially due to micro exfoliation (fatigue of the tread). Although there is no officially expressed maximum limit, the percentage ratio of axial and radial loads considered acceptable for a two-row radial roller bearing is about 25%.

Another improved construction solution presented in the paper is the *Wear Resistant Two-Row Roller Oscillating Radial Roller Bearing* that uses special coating technology in combination with improved work surface finishes. This paper also presents the experimental research on solving the problems associated with oscillating radial bearings with barrel rollers.

2. METHODOLOGY

2.1. Failure aspects

During the operation of the wind turbine there are several aspects that depend on the reliability and maintenance of the bearings. Micro-exfoliation, insufficient lubrication, bearing material, imposed operating conditions, equivalent pressures and stresses (von Misses) on the outer and inner ring, roller stresses, total deformation, lifespan cycles and tangential stress on the rings and cage, are important issues that we will address further. This state of affairs leads to significant premature failures during the turbine operating period. [4]

Micro-exfoliation- the main shaft bearings in three-point bearing turbines have the same failure modes, including micro-exfoliation, roller overload, roller head axial overload, monobloc cage failure, central guide ring and cage wear, and due to particulate contamination.

Insufficient lubrication-In addition, the operating conditions of the main shaft bearing are not at all favorable for the generation of the lubricant film. [3] With a maximum operating speed of approximately 20 rpm, the linear speed of the bearing work surfaces and the generation of the lubricant film are often insufficient to keep the micro asperities of the raceways and rollers separate. In addition, the torque and torque acting on the turbine rotor constantly change the position and direction of the bearing loading area - and this, almost instantly. Thus, the formation of the lubricant film is interrupted and its quality suffers.

2.2. Choosing improved solutions

For the direct replacement of bearings mounted in existing wind turbine fleets, a *Wear Resistant Double Row Oscillating Roller Bearing* has been developed [2], [7], [8] using a special coating technology in combination with improved finishes.

- **Wear resistant bearings**
- **Tapered roller bearing**

Table 1. Features and benefits of the wear-resistant two-row radial barrel oscillating roller bearing. [2], [6], [7]

Technology	Description	Benefits
roller finishing	low roughness, isotropic finish	low tensions and contact between micro asperities
special surface coverage of the rollers	amorphous hydrogenated carbide reinforced with tungsten carbide (type coverage); thickness 1 µm	increases wear resistance and durability, increases resistance to hard particle contamination
optimized internal geometry	tread and roller compliance	reduces the tension on the rollers, reduces the risk of tilting the roller, creates favorable traction
2-part cage	2-part cage, made of brass, mechanically processed	reduces operating forces

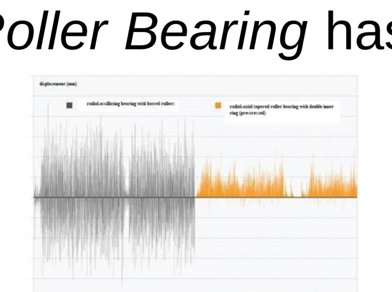
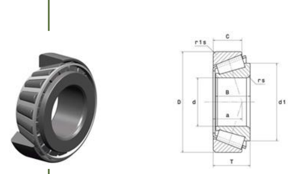


Figure 6. Chronological representation of the axial displacement of the main shaft.

2.3. Data testing and simulations

The axial radial with tapered rollers with double inner ring bearings [8] were tested (Figure 7).

As it can see the cylinders rotate in the small ring but are tangent to the large one (Figure 8). Size for bearing are: inner diameter - 70 mm; outer diameter - 160 mm; rollers / cylinders – 10; roll / cylinder diameter - 26 mm; bearing height / thickness - 35 mm. Material used: structural Steel (Table 2). Conditions imposed: the inner ring must not move- cylindrical support (Fig. 9); modeling the shape of study bearings (Fig. 10, Fig.11);



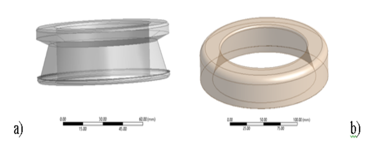
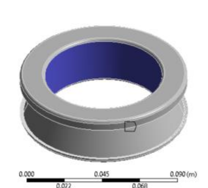


Figure 8. The rings of bearing-a) inner ring; b) Outer ring - has a conical shape on the inner face.

Table 2. Technical data for structural steel.

Type	Value
Density	7 850 kg/m³
Isotropic Elasticity Derive from: Young's Modulus	2e+11 Pa
Poisson's Ratio	0.3
Bulk Modulus	1.6667e+11Pa
Shear Modulus	7.6923e+10 Pa
Isotropic Secant Coefficient of Thermal Expansion	1.2e-05 1/°C
Tensile Ultimate Strength	4.6e+08 Pa
Tensile Yield Strength	2.5e+08 Pa



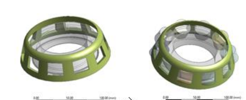


Figure 10. a) Inner ring with support rail; b) Inner ring with support rail + inclined rotating cylinders / rollers.

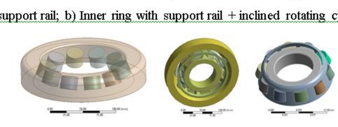
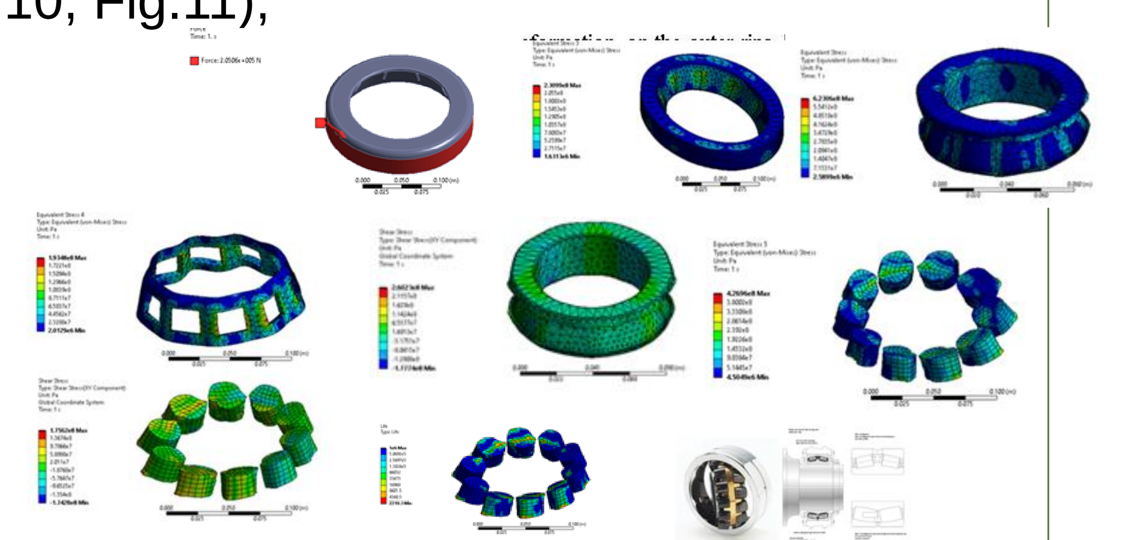


Figure 11. The simulation of shape of the row axial tapered roller bearing.

4.RESULTS



- The force of 2.05 • 10^5 Pa is evenly distributed on the outer surface of the outer ring (Fig. 12);

Equivalent (von Misses) stress on outer ring (Fig.13), on the cage (Fig.14) and on inner ring (Fig.15);

Shear stress on  (Figu.16);Equivalent tension (von Misses) on rollers (Fig.17); The total deformation [mm] appears on the outer ring, and has a value of 0.005[m...] (Fig. 18);Tangential tension on rollers are shown below (Fig. 19);Lifespan - cycles - minimum 2200 (Fig. 20), after 2200 cycles it is possible for fracturing to begin;Also tested were comparatively: axial radial bearing with two-row tapered roller, prestressed [2], compared to the radial oscillating bearing with two-row barrel rollers, in a standard main shaft (Fig. 21).

5. CONCLUSIONS. . Experimental research has shown that the use of such a two-row radial tapered roller axial bearing, pre-tensioned during assembly, reduces the axial load in the gear speed multiplier by 67% compared to the two-row radial tapered roller bearing. During tests and simulations, the axial radial bearing with two-row tapered rollers showed reduced wear, deformation / load induced in the gear multiplier with lower gears (no additional load on the torsion arms) and increased system rigidity.

REFERENCES: [1] Fierro T/Timken, "The durability of the main shafts of wind turbine" Journal of Mechanical transmissions, **1** 17-10 (2019) . [2] Fierro T/Timken, Journal of Mechanical transmissions, **2** 10-12 (2019). [3] DOUGLAS L, [Improvements to bearing construction solutions for existing turbines], The Timken Company, North Canton, Ohio, U.S, II, 10-12 (2019).