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FEM approach for the maximum strain investigation of wind turbine gear failures considering seasonal variability

Introduction: The failures of wind turbine (WT) gearboxes have notably had a significant influence on the annual energy production obtainable from wind turbines, thus consequentially influencing the ability of wind farm developers to meet up with the expected amount of power sent to the national grid [1]. This has triggered a FEM approach for the failure investigation of this essential component. This study used the finite element method (FEM) to investigate failures in gears by analyzing the maximum strain criteria, which reflects the largest deformation of a material and offers a clear indicator of failure modes. FEM was considered because it takes into account the complexity of gear geometries and offers commendable accuracies [2]. However, this accuracy comes at the cost of increased computational time. To address this, the CHPC cluster was employed to carry out this computation.
Objective: To investigate the effect of the two prevalent failures (cracking and pitting) on the maximum strain criteria in the planetary stage of a WT gearbox under dynamic loading from different South African climatic conditions.
Methodology: FEM technique was utilized to examine the impact of dynamic loads from different seasons (winter, spring, summer, and fall) in the Western Cape, South Africa on healthy and faulty sun gear of the WT gearbox model. The authors extracted the maximum equivalent strains representing the deformation per millimeter for the gears meshing under different seasonal dynamic loadings from the solved model considering healthy, cracked, and pitted teeth. The extracted maximum strain responses for the healthy and failure investigations were examined, contrasted, and presented. This investigation was carried out in the ANSYS Workbench 2021 R2 for FEM simulations and using computational resources from CHPC.
Results/Findings: The study analyzed maximum strains in healthy gears and those with cracks or pitting during different seasons. Across all the four seasons, the overall maximum strains varied between 0.0061 and 0.0072 for healthy gears, 0.0077 and 0.0088 for cracked gears, and 0.0149 and 0.0160 for pitted gears, with summer season exhibiting the highest strain due to inherent increased load. Comparing failures, cracks had a 25.16% average difference from healthy results, while pitting had a much larger impact at 135.86%. This shows that the maximum strain criterion performs better for surface failures like pitting, which typically experience higher strains in the face of the meshing teeth transmitting load.
Conclusion: The FEM approach was successfully used to estimate gear strains considering different seasons of the year. These results can help to provide a reasonable projection of the impacts of seasonal wind loads of a proposed wind farm on critical components and thus implementing preventive measures. Also, by comparing simulated sequences with measured signals during operation, it is possible to diagnose and classify occurring failures more accurately, boosting confidence in the wind industry.
HPC Content: The FEM analyses in this investigation were solved using computational resources and the Ansys Mechanical software from CHPC. The CHPC cluster was efficiently utilized by employing the solver's pre-written files (input file and job script). Individual input files were created from the dynamic models developed on a personal workstation. The input files were transferred to the appropriate directory on the CHPC cluster awaiting submission. The job script launches the Ansys Mechanical solver and runs the simulation of the specified input file. The computations took an average of 12-14 hours to solve with 24 assigned cores and 99% efficiency.
REFERENCES
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