TRANSNAV
http://www.transnav.eu
the International Journal on Marine Navigation and Safety of Sea Transportation
Volume 17 Number 3 September 2023
DOI: 10.12716/1001.17.03.07

Considerations Regarding Oiling System for Offshore Wind Turbines

M. Panaitescu, F.V. Panaitescu, G.P. Panait & A.A. Scupi
Constanta Maritime University, Constanta, Romania

ABSTRACT: Power from renewable sources would play a key role in the future of electricity .The wind energy is one of the goal of EU's commitment, which want to develop offshore wind potential [1], [2]. Lubrication of wind turbines is very important for maintenance [3] . The purpose of this paper is to present some considerations about monitoring oiling system. This system monitors kinematic data in real time. The importance of monitoring real data with this system help us to simulate lubrication for various types of wind turbine reducers in order to choose the optimal form of the lubrication system and for good maintenance.

1 INTRODUCTION

The European Union aims to be climate neutral by 2050, an objective included in the European Green Deal and in line with the EU's commitment to action global measures to combat climate change, taken together with the Paris Agreement. Power from offshore renewable sources would play a key role in achieving this goal. According to the estimates of the European Commission, electricity will represent at least 50% of the total energy mix in 2050, and 30% of future electricity demand will be provided by offshore wind energy.

“The European Commission estimates that 240-450 GW of offshore wind power is needed by 2050 to achieve this goal [1]. She is determined to drive development offshore wind and explore its potential in the seas and along the coasts of Europe, respecting, at the same time, the ecological limits of natural resources and the interests of others maritime users” [2, 3]. There are currently 110 offshore wind farms (OWF) in operation with over 5,000 wind turbines. Negative effects could occur throughout the life cycle of an offshore wind turbine, on during the construction, operation and decommissioning stages. Lubrication of wind turbines is very important during their operation. The purpose of this paper is to present a description of functionality of the condition monitoring system and of the influence of metal particles in oil system [4].

2 MATERIALS AND METHODS

The wind turbine has automatic lubrication on subsystems: blades, hub, gearbox, brake, etc. (Figure 1) [5].

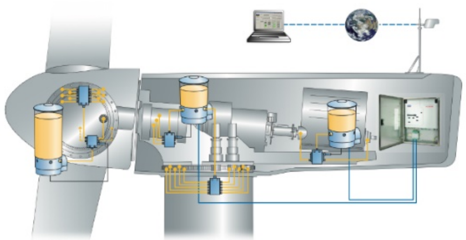


Figure 1.Wind turbine circuits of lubrication.

Lubrication systems guarantee machine durability and eliminate downtime.

2.1 *The lubrication of wind turbine blades*

In automatic operation, the bearing lubrication is continuously operated at an interval at 6 hours (can be parameterised). In this connection, the grease pump and the 3/2 directional solenoid control valve are simultaneously actuated by the plant control via a coupling relay. The power supply ensues via an automatic circuit breaker of the turbine electric (Figure 2)[3].

The duration of the lubricating interval must be determined in tests at various temperatures. It not exceed 20 minutes. The pump builds up pressure in the lines which causes all the distributors to be supplied with grease. The plant control switches of the grease pump and of the 3/2 directional solenoid control valve at the same time. The distributors deliver their lubricant to the bearing and the pressure switch is reset.

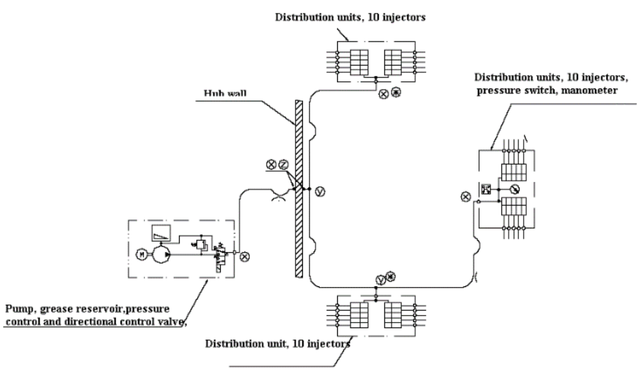


Figure 2. Lubrication pump circuit [3]

If external faults occur during automatic operation, lubrication is halted and continued again at the point where it was interrupted after the fault has been eliminated.

2.2 *The monitoring oily system*

This system monitors kinematic data and receives real data for power from main controller of wind turbine (Figure 3)[6].

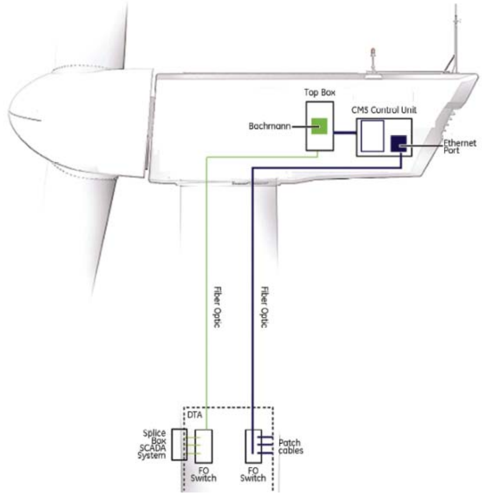
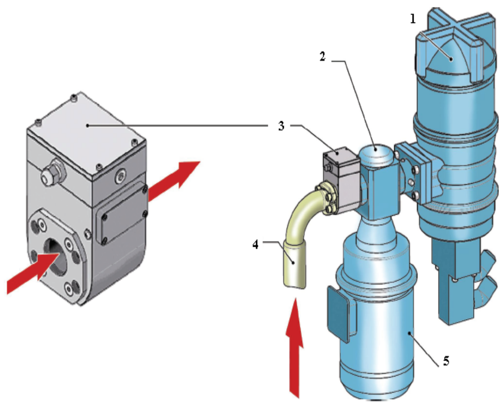


Figure 3. Oiling automatic monitoring system [6]

Also, the sensor of this system detects metallic particles in the oiling system (Figure 4) [6]. When detect any vibration pattern deviation, respond by sending an signal alarm through the network system, which is connected with the wind turbine's top box. This box transmitted output to control unit of monitoring system and after to an external personal computer. All real data are monitoring with SCADA system. The importance of monitoring real data with this system consists in: configuration of the system with dive train kinematic data, fibber optic cable for all communications between top box, monitoring system and nacelle, software tools for data analysis.



1-filter assembly; 2-lubrication pump; 3- metal particle sensor; 4- suction hose; 5-motor.
Figure 4. Lubrication system with metal particle sensor [6]

2.3 *The simulation of lubrication on wind turbine gearbox*

The recent technology suggests using a pinion to automatically lubricate open gears. This type of monitoring real data is useful to simulate lubrication for various types of wind turbine reducers in order to choose the optimal form of the lubrication system and for good maintenance.

There are several types of gearboxes, the gears varying in number between 4...7 as well as in size (Figure 5)[7].

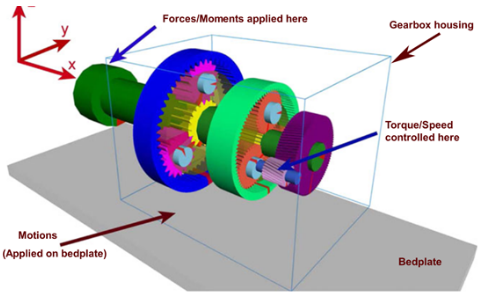


Figure 5. The structure, forces and motions of wind turbine gearbox.

"The statistical analysis and the graphical presentation of the results of oil analyses are very helpful tools when assessing the technical condition of machines. Based on the precise data obtained from the analyses, the operators are able to maximize the production potential of the machine park and plan in advance any required service activities. Regular lubricant monitoring is an excellent tool that provides a rich information on the technical condition of machines "[9, 10, 11, 12, 13].

For simulation in 2 D the influence of metal particle in oiling system of wind turbine, was proposed a gearbox with two toothed wheels (Table 1)(Figure 6):

Table 1. The wind turbines normally gearbox data.

Gearbox with two toothed wheels	Diameter [mm]	Number of teeth
1 wheel	120	20
2 wheel	360	60

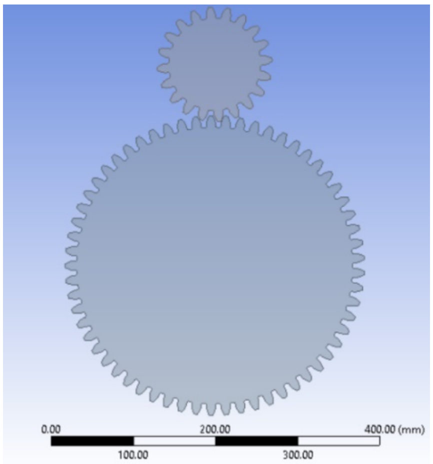


Figure 6. Gearing of the wheels in the wind turbine gearbox.

The presence of oil in the gearbox is shown in figure 7:

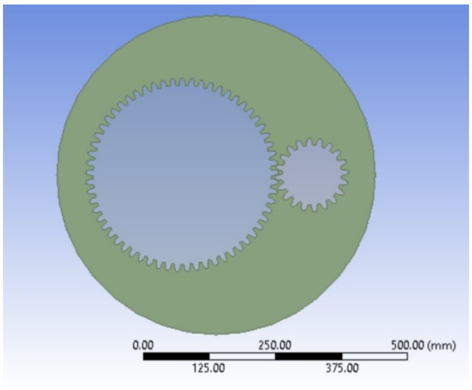


Figure 7. The oil inside of gearbox.

The oil occupies 75% of the casing volume. The discretization network – Mesh consists of 49000 elements (Figure 8):

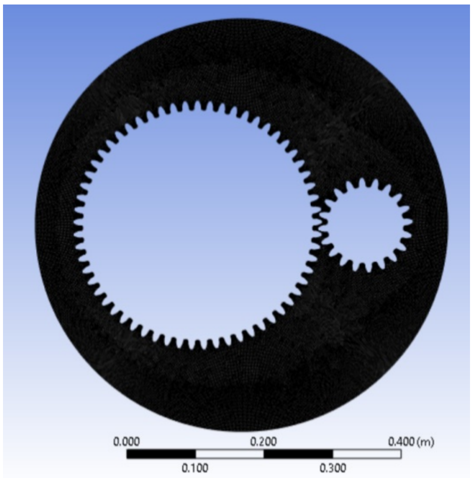


Figure 8. The discretization network.

Boundary conditions - boundary limits are the following:

- The Eulerian model used with 3 phases (Figure 9):
  - Phase 1 liquid oil with a density of 890 kg/m^3;
  - Phase 2 solid – sawdust – scrapings, with a density of 8000 kg/m^3, occupies 2% of the oil volume;
  - Phase 3 gaseous air with a density of 1.22 kg/m^3.

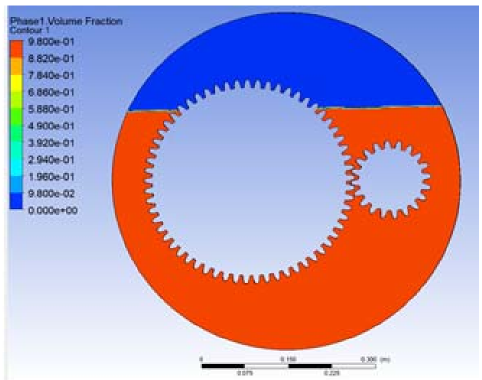


Figure 9. Distribution of the 3 phases in the gearbox.

All obtained results support interpretation.

3 RESULTS AND INTERPRETATIONS

The results obtained are:

– Static pressure distribution - increases with depth (as expected, Figure 10);

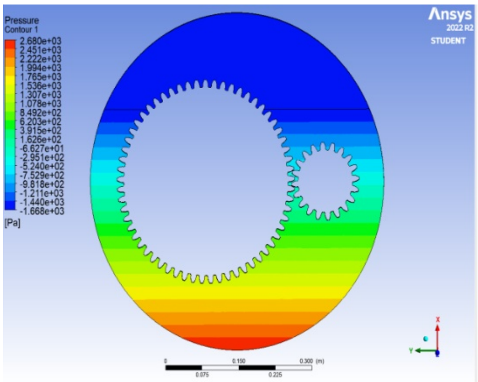


Figure 10. Static pressure distribution.

– The presence of metal in the lubricating oil is visualized by the filings, which are uniformly distributed in the oil. The wheels don't turn. The sawdust is gravitationally pulled down (Figure 11);

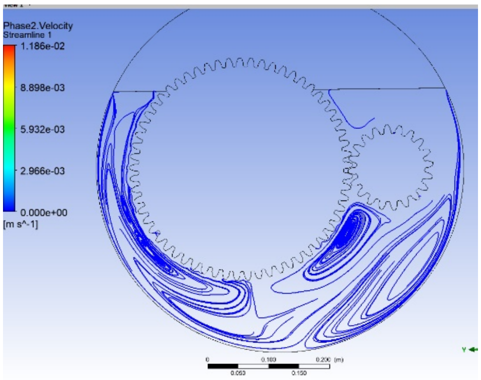


Figure 11. The metal streamlines in the oil.

– In phase 2, the streamlines show us how the filing slides gently towards the base of the gearbox (Figure 11, Figure 12);

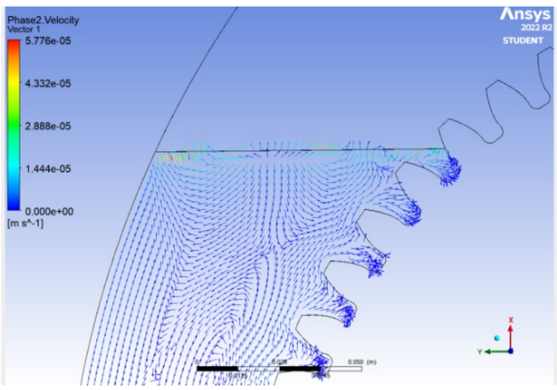


Figure 12. The distribution of sawdust towards the base of the gearbox.

The interpretations of these results are:

– A part of the pleat is drawn into the upper layer, at the contact surface of the oil with the air, due to the surface tension, but its speed is very low, the maximum value reaching 0.00005 m/s;
– It was then imposed that the gears rotate like this:
  – the larger one with 20 rpm in the trigonometric sense,
  – the small one with 60 rpm clockwise.

The maximum speed is reached on the outside of the gear teeth and has a value of 0.438 m/s.

– When the gears get out of mesh, suction is applied and the filings are drawn to the teeth (Figure 13);

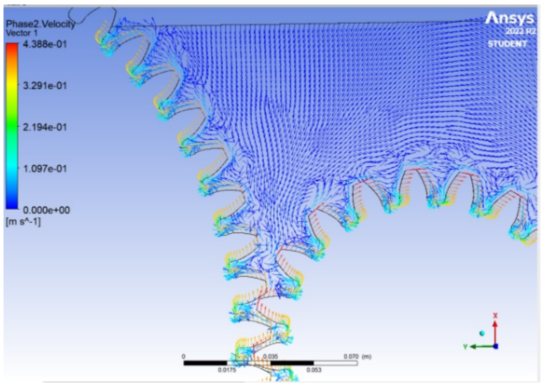


Figure 13.The distribution of filings- gears get out of mesh

– When the gears get in mesh, the compression is done [12] and the filing is pushed out of the teeth of gear (Figure 14);

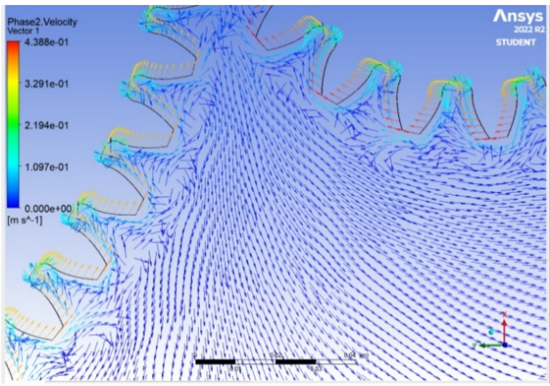


Figure 14.The distribution of filings- gears get in mesh .

– The streamlines take the form of gear wheels (Figure 15);

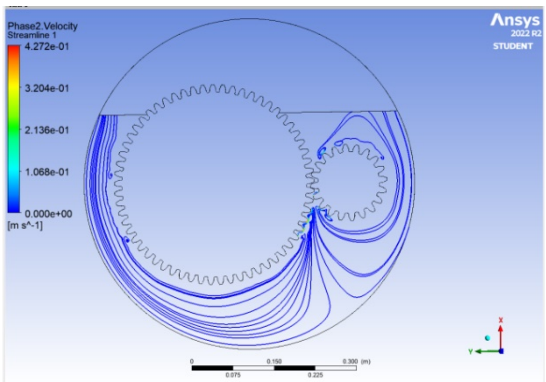


Figure 15. Phase 2-Velocity streamlines.

After a few seconds of rotation, the following aspects appear:

- The turbulence increases a lot around the gears [9, 10], a phenomenon visualized by the distribution of the velocity vectors (Figure 16, Figure 17) and the current lines (Figure 18).

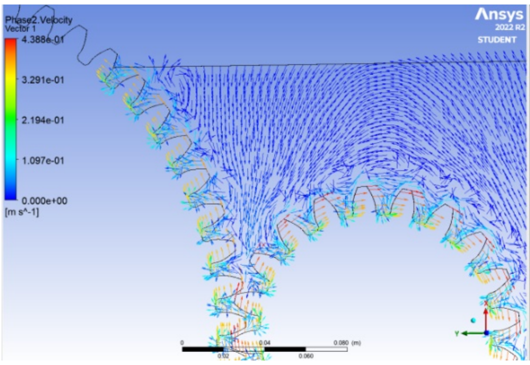


Figure 16. Phase 2-Velocity vectors distribution.

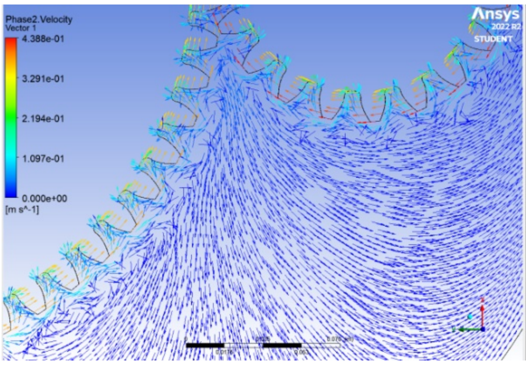


Figure 17. Phase 2-Velosity distribution after few seconds.

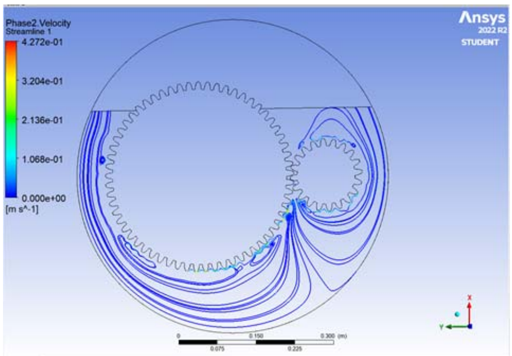


Figure 18. Phase 2. Streamlines distribution.

Finally, can observed:

- the maximum value of speed when the gears get in mesh is $4.388.10^{-1}$ m/s;
- the maximum value of the streamlines velocity is $4.272.10^{-1}$ m/s;
- when the turbulence increases a lot around the gears, the maximum value of velocity vectors is $4.388.10^{-1}$ m/s.

4 CONCLUSIONS

This system which is used for monitoring in real time a metal particles is useful because sent a signal to every 145 seconds to the monitoring device when a particle is detected. When appear a fault, a fault signal is sent to the controller of automatic control oiling system. These changes in the operational parameters of the wind turbine are influenced by climate changes, changes in temperatures, pressures, loads generated by changes in wind speeds. The costs of repairing or reconditioning some systems, generated by the lack of continuous or defective monitoring of the wind turbines' operation, are very high, especially the costs for gearboxes. The greater the wind force, the most vulnerable the gears are. In this case, the offshore wind turbines are the most susceptible to damage. The gear wheel teeth must have appropriate bending strength as well as strength. The dangerous moment appear when the teeth contact each other in the area of the pitch circles where no slip occurs, then mean the oil film is missing.

ACKNOWLEDGMENT

Authors gratefully acknowledge to this material support path received under **Project BLOW2023-2028- Black Sea FLoating Offshore Wind**, Grant Agreement Nº: 101084323.

REFERENCES

[1] Peshco V., Mendel B., Muller S., Markones N., Mercker M., et.al., " Effects of offshore windfarms of seabird abundance:Strong effects in spring and in the breeting season ", Marine environmental research, 2020

[2]https://www.europarl.europa.eu/meetdocs/2014_2019/plmrep/COMMITTEES/PECH/DT/2021/03-17/1217673RO.pdf

[3] https://gewindenergy.com, ** GE Documentations Wind Turbines Systems, 2009.

[4] Panaitescu F.V., Panaitescu M., Juganaru D.E.," Monitoring and data acquisition for a consumption system based on renewable energies", Int. Journal of Modern Manufacturing technologies, Vol. XIV, no.3, pp 184-190, DOI 10.54684, 2022.

[5] https://lubemec.grouphes.com/wind-power-lubrication-maintenance, **"Automatic lubrication solutions", 2023.

[6] https://gewindenergy.com, ** GE Documentations Wind Turbines Generator Systems GE 2.5 xl, 50 Hz, 2009.

[7] https://www.lubetechnologies.com/wind.html, " Wind powqer generation-Lubrication systems for wind turbines ", 2023.

[8] J. Ukonsaari, N.Bennstedt, " Wind Turbines gear box", Energiforsk Journal, 47, 2016.

[9] Krzysztof Płonka, " Lubricating oil analysis in wind turbines gearboxes – part 1", available on https://www.ecol.com.pl/en/lubricating-oil-analysis-in-wind-turbines-gearboxes-part-1/.

[10] Bejger, A., Frank, E., Bartoszko, P., "Failure analysis of wind turbine planetary gear", Energies Journal, 14, 6768, http://doi.org/10.3390/en14206768, 2021.

[11] Latiffianti E., Sheng S., Ding Y., " Wind turbine gearbox failure detection through cumulative sum of multivariate time series data ", Energy Journal, vol.10, https://doi.org/10.3389/fenrg.2022.904622, 2022.

[12] Park, C., Huang, J. Z., and Ding, Y. " A Computable Plug-In Estimator of Minimum Volume Sets for Novelty Detection. Operations Res. 58, 1469–1480. doi:10.1287/opre.1100.0825, 2010.

[13] Pang, B., Tian, T., and Tang, G.-J. " Fault State Recognition of Wind Turbine Gearbox Based on Generalized Multi-Scale Dynamic Time Warping", *Struct. Health Monit.* 20,3007–3023. doi:10.1177/1475921720978622, 2021.