Norwegian University of Science and Technology

A review of prognostics for offshore wind turbines

Wanwan Zhang[1], Jørn Vatn[1], Adil Rasheed[2]

[1]Department of Mechanical and Industrial Engineering
[2]Department of Engineering Cybernetics

EERA DeepWind 2022

1- Paper Selection

Keywords: **"wind turbine" AND "remaining useful life"**

Searching:

- IEEE (n=45)
- Scopus (n=125)
- Web of Science (n=118)
- Springer (n=151)

Q1: Read abstracts and remove irrelevant literature

Screening:

- IEEE (n=6)
- Scopus (n=54)
- Web of Science (n=72)
- Springer (n=10)

Q2: remove duplicated literature

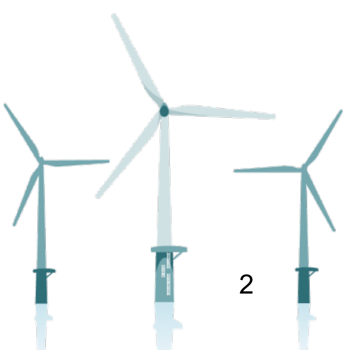
Eligibility:

Paper included (n=141)

Q3: Assess full text

Included:

Final (n=114)



2- Overview of the Literature

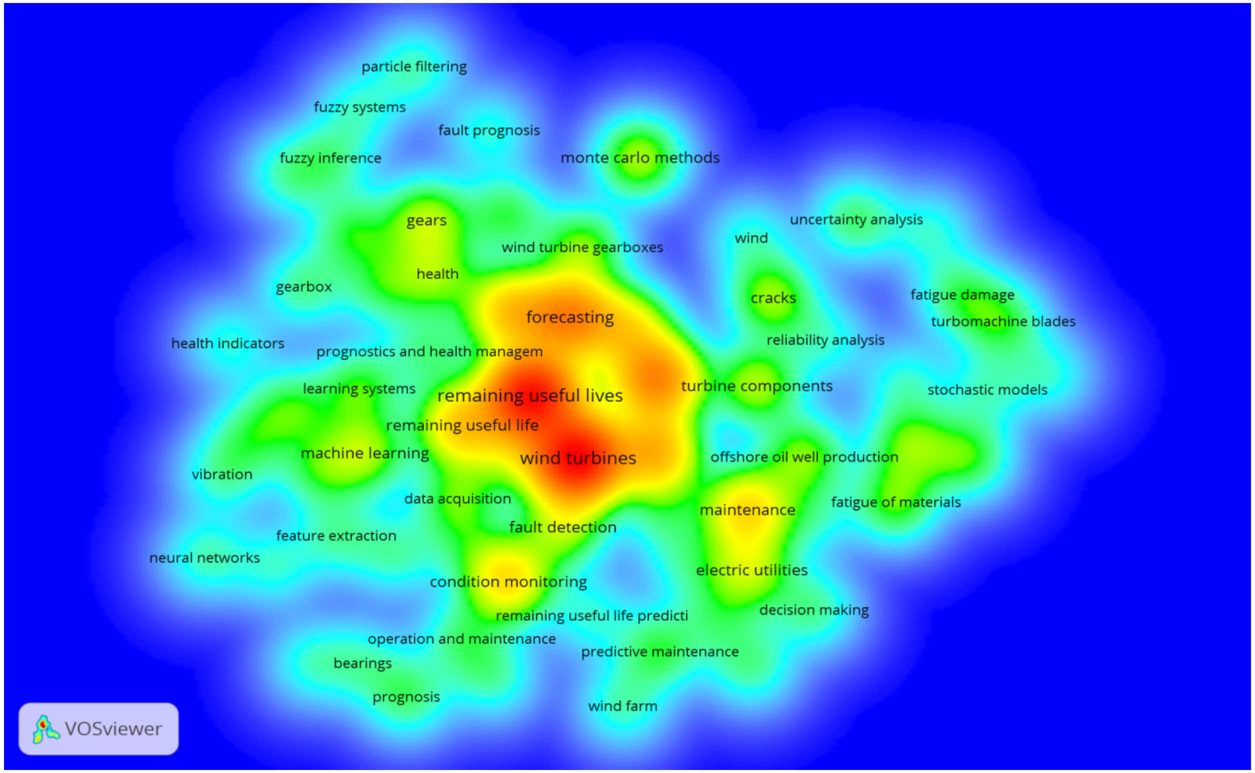


Fig 1. heatmap of key words from Scopus

Remaining useful life (RUL): An estimate of how long the object runs from the current state to the state where it reaches the failure threshold (Vachtsevanos et al., 2006; Saidi et al., 2021).

Predictive maintenance (PdM): Condition based maintenance carried out following ***a forecast*** derived from repeated analysis or known characteristics and evaluation of the significant parameters of the degradation of the item (EN 13306, 2009).

Prognostics and health management (PHM): a complete industry maintenance and asset ***management approach*** utilizing signals, measurements, models, and algorithms to detect, assess, and track degraded health, and to predict failure progression (Kalgren et al.,2006; Zonta et al.,2020).

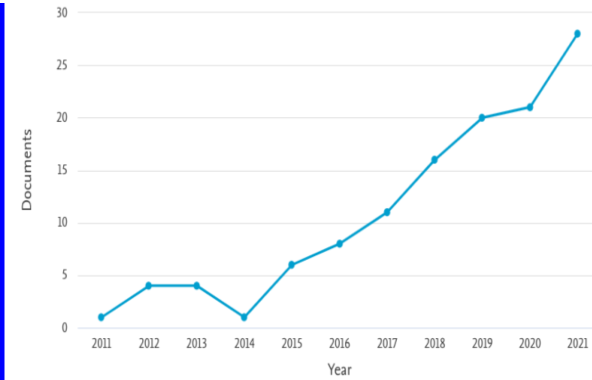


Fig 2. Trend of publications

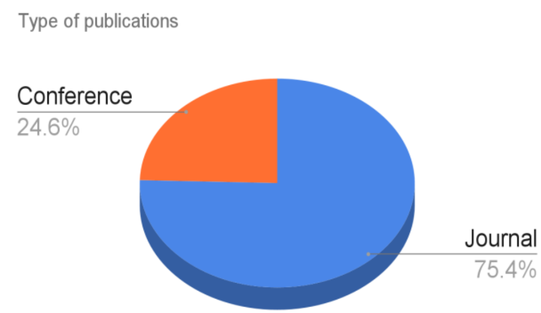


Fig 3. Type of publications

3-Taxonomy of Prognostics models

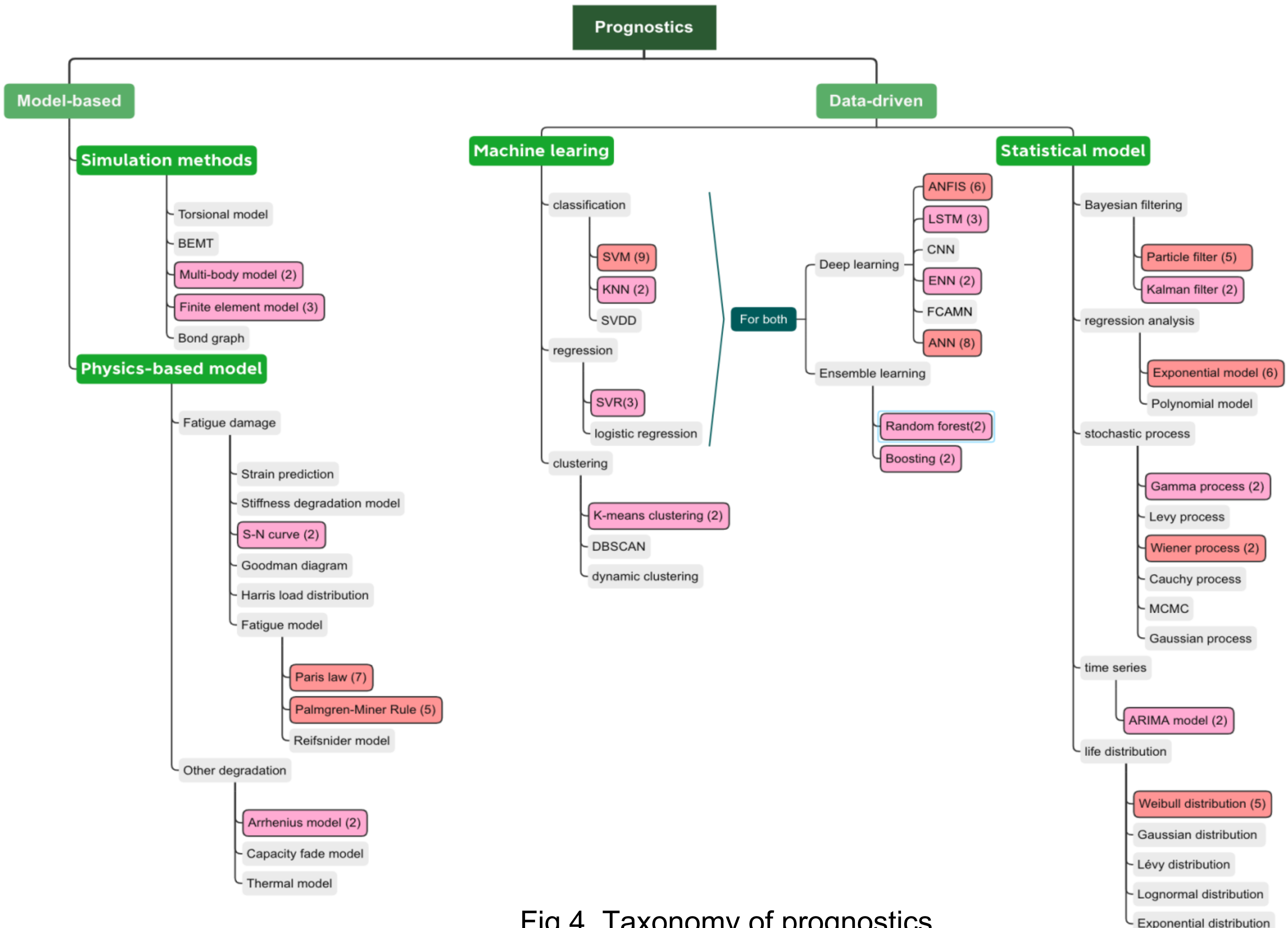


Fig 4. Taxonomy of prognostics

4-Opportunities in hybrid modelling

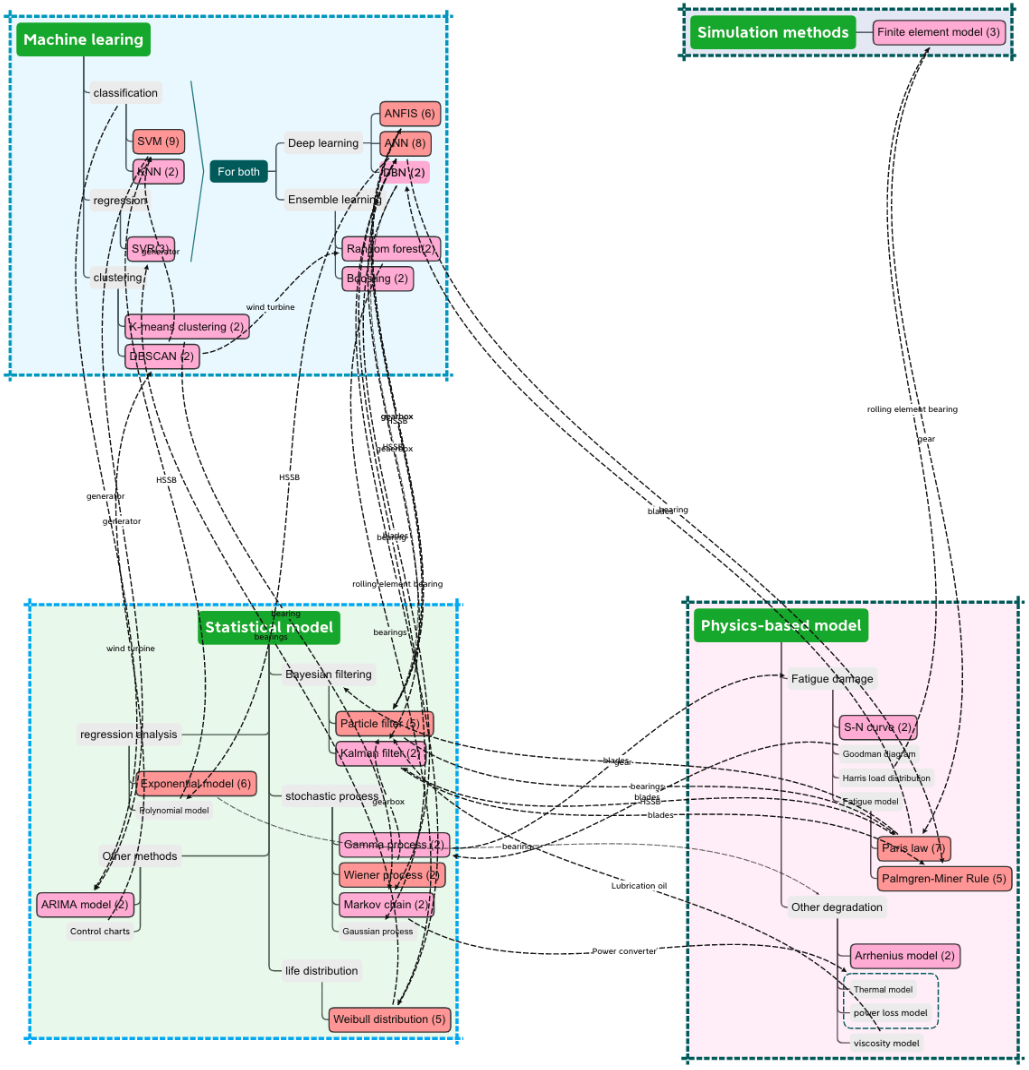


Fig 5. Connections among models

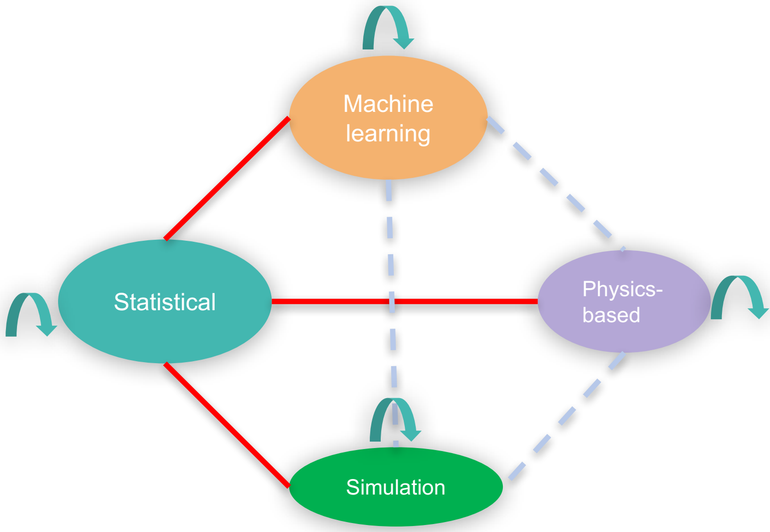


Fig 6. Hybrid models

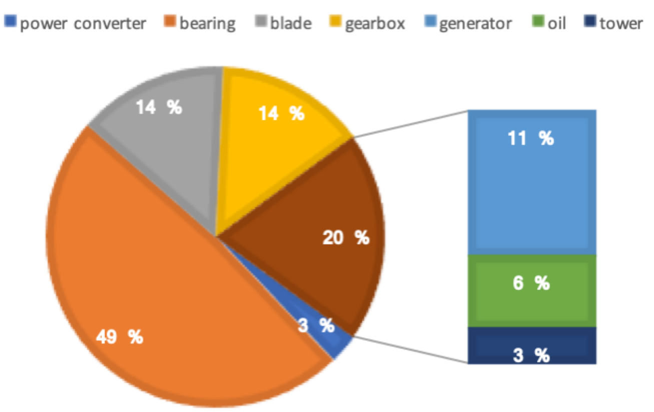


Fig 7. Studied Components

5-Challenges and Opportunities

Data processing:

- **Limited failure data**: The large amount of run-to-failure data is hard to access in due to the design of long lifetime and the huge cost of failure. However, the lack of failure data often confines the validation of approaches. Data-driven approaches relies on the quality and size of data to develop.
- **Heterogeneous data**: SCADA system or installed sensor send a large amount of operation data, such as environmental data and power data. Preprocessing and fusing the heterogeneous data is the important step before the data is fed to PdM models. It is challenge to research and summarize how these data should be selected on componnts level and system level, since it requires multidisciplinary knowledge in physics, signal processing, statistics and machine learning.
- **Experimental data:** for bearings, shaft, gearbox, experimental data can be available. It is useful to investigate how to utilize the experimental data to help construct the PdM model.

The development of hybrid model:

- For machine learning model, the area of deep learning, ensemble learning, image-based methods can be explored for predictive maintenance. The combination of different machine learning methods can offset the disadvantages of different models. It is also possible to research the explainable artificial intelligence methods to increase the interpretability of machine learning methods.
- The dimension reduction methods (PCA, SOM, Isomap) in statistics and machine learning are often used as the method for feature selection of other models. Statistical model is widely connected with the other three models and becomes the core. It is an opportunity to develop the connection among simulation model, machine learning model, physics-based model. There also lacks the accurate definition and classification of physics model. Most of the physics models are based on fatigue and some are about chemical reaction. The simulation model is rarely applied and needs specific knowledge to build the system.
- There are no standard evaluation metrics of good models. The concepts of good model in machine learning and other areas are different. A multidisciplinary standard can be proposed to assess the performance of different models or hybrid models.

References

Vachtsevanos, George J., and George J. Vachtsevanos. *Intelligent fault diagnosis and prognosis for engineering systems*. Vol. 456. Hoboken: Wiley, 2006.

Saidi, Lotfi, and Mohamed Benbouzid. "Prognostics and Health Management of Renewable Energy Systems: State of the Art Review, Challenges, and Trends." *Electronics* 10.22 (2021): 2732.

Standard, E. U. "EN-13306-Maintenance Terminology." (2009).

Kalgren, Patrick W., et al. "Defining PHM, a lexical evolution of maintenance and logistics." *2006 IEEE autotestcon*. IEEE, 2006.

Zonta, Tiago, et al. "Predictive maintenance in the Industry 4.0: A systematic literature review." *Computers & Industrial Engineering* (2020): 106889.