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EXTENDED ABSTRACT

Predicting the remaining life of offshore structure members with random forest algorithm

Touraj Taghikhany[a,*], Mohammad Nabi Nazari Ghalati

[a] *Faculty of Civil Engineering, Amirkabir University of Technology (TehranPolytechnic), Tehran , Iran*

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1. Introduction

Considering the importance and high cost of construction and maintenance of offshore platforms for the purpose of oil and gas extraction, and considering the fact that in case of failure, they can cause many environmental disasters, technical inspection of their structural condition is of serious importance. In addition to the high cost, this does not cover all aspects and it is very difficult to detect the failure in this case. Due to the repetitive nature of most of the environmental loads in the seas, these structures are constantly exposed to multiple and repetitive loadings. The phenomenon of fatigue is one of the effective factors in the health of these types of structures, so that during the past decades, the offshore industry has witnessed unfortunate events that often occurred due to the phenomenon of fatigue. One of the unpleasant cases can be mentioned the disaster of the Norwegian semi-submerged oil platform in the North Sea, named as the Kyland Alexandria, in which 123 people of the platform's crew lost their lives. One of the main braces connected to the base of the pontoon was completely broken and separated from the platform, causing the platform to completely overturn. The semi-submersible rig Sedo 135, which began operating in the Gulf of Mexico in 1965, suffered a fatigue failure in one of its rigs in 1967 after two years. One of the most widely used platforms in the Persian Gulf is the fixed platform of the stencil or jacket type, which is a steel structure that has braces and a deck, and foundations that are fixed on the sea floor by numerous piles. Fatigue cracks are the main failure factor in fixed jacket platforms (Ibrion et al., 2020).

Therefore, this research is looking for a smart and integrated solution to estimate the remaining life of structural members, which can estimate the remaining life of its members with appropriate speed and accuracy even if there is a large amount of information. Here, to predict the remaining life, different failure scenarios are formed and in each scenario, the structure is subjected to environmental loading based on the data recorded in the Persian Gulf. In the following, using fatigue analysis by spectral method in SACS software, the remaining life of each element is obtained. A data set including the characteristics of each failure scenario along with the shortest remaining life of the element in each level and type of element is formed and it is used to train the random forest algorithm. This algorithm, which is one of the well-known algorithms in machine learning theory for data classification, is used to predict the remaining life of members in other scenarios and its effectiveness is checked (Ehsani et al., 2022). Therefore, in order to get familiar with the basics of the method used, we will first explain the theories of fatigue and then proceed to model the intended platform along with the failure scenarios. Then, we will implement the method and estimate the remaining life of different scenarios from the data set and its training.

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* Corresponding Author
E-mail addresses: ttaghikhany@aut.ac.ir (Touraj Taghikhany)

2. Methodology

2.1. Fatigue

Due to the periodic nature of some loads, such as the effect of waves on marine platforms, the phenomenon of fatigue and damage caused by it can be considered one of the main factors of failure in the structure and reducing its service life. The noteworthy point here is that due to the phenomenon of fatigue, capillary cracks have been created in the member, and the severity of these cracks increases due to secondary factors such as corrosion, which is very common in steel structures. Therefore, it can be concluded that the effect of fatigue on the calculations related to determining the remaining life of a structure directly (as a main failure factor) or indirectly (as a failure initiating or intensifying factor) plays a key role. To estimate the fatigue of the existing structures, we use the classical approach, in which the Palmgren-Miner curves, which are based on the law of cumulative damage, are used to calculate the fatigue life.

2.2. Platform modeling and data collection

The intended platform is a fixed platform with a jacket-type stool in the South Pars region and 100 km southwest of Akhtar village in Bushehr province, which has a water intake depth of 61 meters. The structure of this platform was first modeled in SACS software under dead, live, environmental and operational loads. This platform consists of three height panels, each panel consists of three types of structural elements (bases, horizontal brace, vertical brace). The damage considered in this research is considered from the method of reducing the cross-section of structural members. This cross section reduction is applied in 4 general modes for 10%, 20%, 40% and 60% and defined in different simple and combined damage scenarios.

Fatigue analysis in the SACS program has been performed by the Fatigue subset in a spectral way .Then, after performing the fatigue analysis, the remaining life results of the structural members for 75 failure scenarios were collected as a dataset for the random forest algorithm.

3. Results and discussion

After considering the health status of the structure as the input of the algorithm and the remaining life of the most sensitive structural element as the output of the algorithm, and the data set was formed, the algorithm was analyzed.

It should be mentioned that the performance indicators of the algorithm in this section indicate good performance in predicting the life of sensitive members of the structure. According to **Table 1**, it can be seen that between the output.The lowest index value of R2 is 0.91, which indicates the accuracy of 91% in determining the remaining life of this algorithm.

3.1. Sensitivity analysis

Using a program written in Python software on the data set to estimate the remaining life of the members, a sensitivity analysis was considered for two sensitive elements of the platform:

For the horizontal brace of the second panel, which is the most sensitive member to the phenomenon of fatigue and has the lowest remaining life, if its health percentage reaches less than 70% (equivalent to 30% failure), it means that the life of these members is less than ten years. Maintenance and repair work should be applied to increase the lifespan of these members.

Next, for the legs in the first panel, which is the second most sensitive member of the structure, if the percentage of health of the structure reaches less than 85% (equivalent to 15% failure), the remaining life of these members is reduced to less than 15 years, and its repair is inevitable.

The last two rows in **Table 1** were removed from the analysis due to the high value of the average remaining life, and this means that these two members are the last members of the structure to give up.

4. Conclusions

In this research, the random forest algorithm was used to predict the remaining life of offshore platform members. The remaining life of the most sensitive element in each panel was considered as output. After performing the fatigue analysis, 75 failure scenarios were considered and using the random forest algorithm, the amount of intelligent detection of the remaining life of the structural members was investigated. The results show that this algorithm has a high ability to detect the remaining life of structural members based on the health status of the structure and is able to predict the remaining life of structural members with high accuracy. Also, with the sensitivity analysis, it was found that if the failure percentage of the legs in the first panel reaches more than 15%, it means that the remaining life of these members has reached less than 15 years and the health of the platform is endangered.

Table 1- Random forest function

Algorithm performance indicators						Hyper parameters of the algorithm			Output	
Test			**Train**							
MSE	**MAE**	**R2**	**MSE**	**MAE**	**R2**	**Number of decision trees**	**Random state**	**Percentage of trainig data**		
3292	36.63	0.96	799.82	18.38	0.98	180	1	80	**Legs**	**First panel**
164757	283.59	0.92	45818	117.68	0.97	180	1	80	**Horizontal brace**	
10.33	4.48	0.94	19.93	1.68	0.93	180	1	80	**Vertical brace**	
12263	93.98	0.91	4122	39.87	0.91	180	100	80	**Legs**	**Second panel**
1.94	0.91	0.97	1.43	0.68	0.92	180	1	80	**Horizontal brace**	
260.13	12.5	0.92	379.41	10.13	0.92	180	100	80	**Vertical brace**	
1024080	795	0.94	593739	455.23	0.97	180	100	80	**Legs**	**Third panel**
–	–	–	–	–	–	–	–	–	**Horizontal brace**	
–	–	–	–	–	–	–	–	–	**Vertical brace**	

5. References

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