Corrosion-Fatigue in Renewable Energy Marine Structures

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Introduction

Fatigue is perhaps the greatest challenge today in the expansion of the capability of wind turbines and invariably reduction of cost of electricity generation in the wind energy sector to meet the Levelised Cost of Energy (LCOE) of £100/MWh target by 2020[1]. Wind turbine support structures are exposed to high cyclic loading caused by wind and normal operations. If in offshore environment, cyclic loading due to waves and sea current will be present.

This research aims at reducing the cost of wind energy through effective and economic design of its support structure. It is expected that the outcome of this research will provide guidance on the prediction of corrosion fatigue life, inspection requirements and economic use of S355 steel, particularly S355G10+M sub-grade in the design of offshore wind turbine support structure.

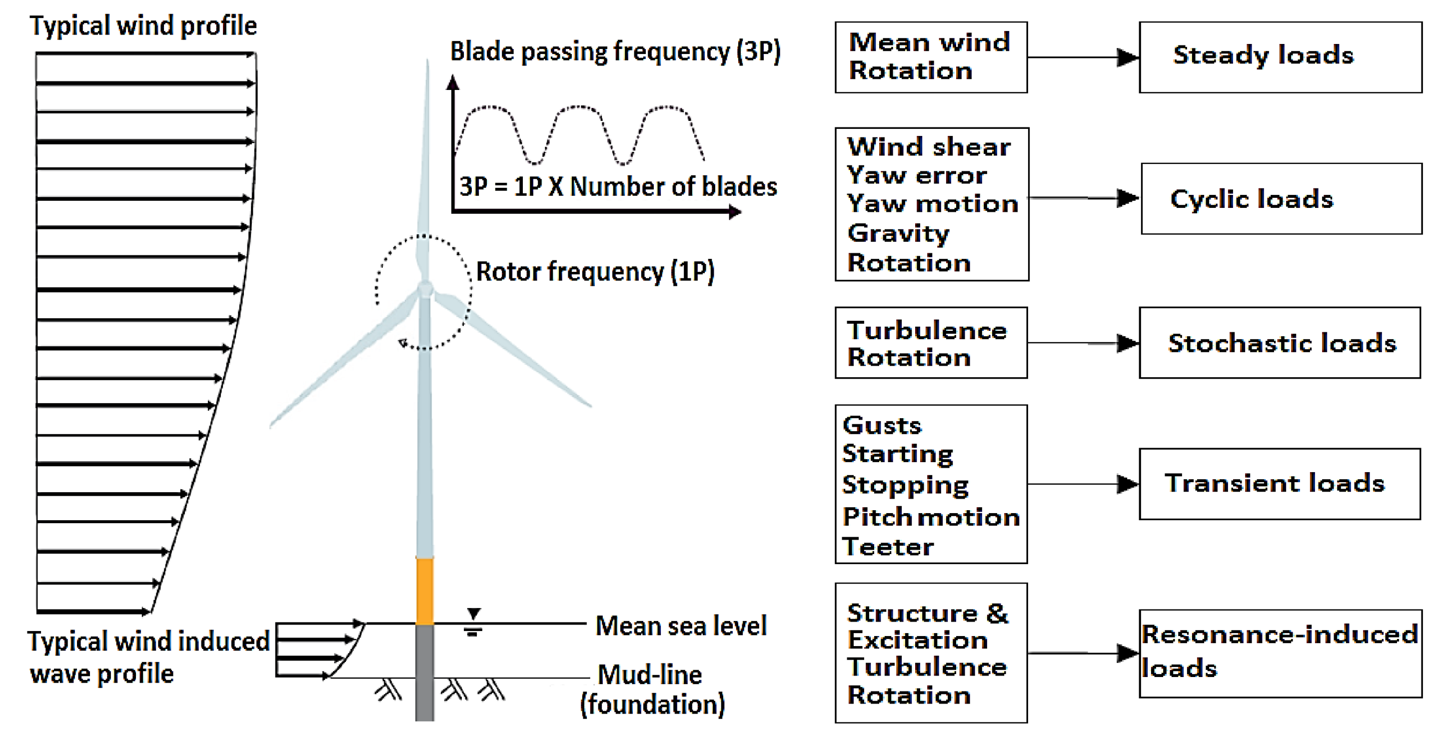

Fig. 1:The main external dynamic and cyclic loading acting on a typical offshore wind turbine [2][3]

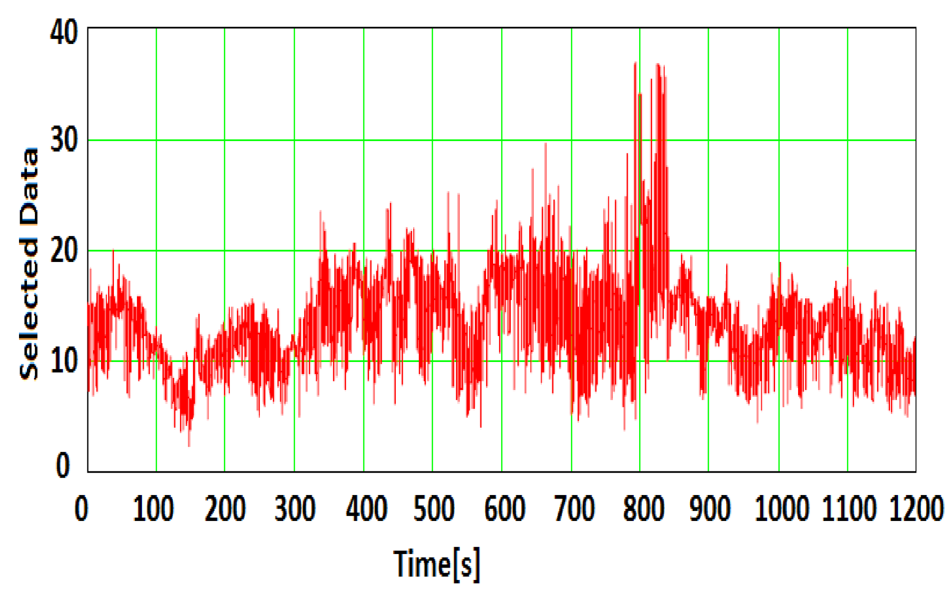

Fig. 2: 30 Minute wind speed record [4].

Name	Rotor Freq. Range (1P) [Hz]	Blade passing Freq. (3P) Range [Hz]
Vestas V66 2 MW turbine	0.18 – 0.41	0.54 – 1.23
Vestas V90 3 MW turbine	0.14 – 0.31	0.42 – 0.90
Siemens SWT-3.6(MW)-107	0.08 – 0.22	0.24 – 0.66
Vestas V120 4.5 MW	0.17 – 0.25	0.50 – 0.75
NREL 5MW WT	0.12 – 0.20	0.35 – 0.60
DTU 10MW RWT	0.10 – 0.16	0.30 – 0.48
3MW Sinovel wind turbine	0.14 – 0.32	0.41 – 0.95

Fig. 3: Typical values of 1P and 3P forcing frequencies for some operational and under development offshore wind turbines

Methodology: To determine the effects of operational frequency, wind loading waveform and mean stress on the fatigue crack growth rate of S355G10+M structural steel in seawater - Instron rig is used to perform the fatigue test and WaveMatrix^{TM} Software is used to simulate sine and holdtime waveforms. Optical microscope and scanning electron microscope are used for post-mortem metallurgical studies.

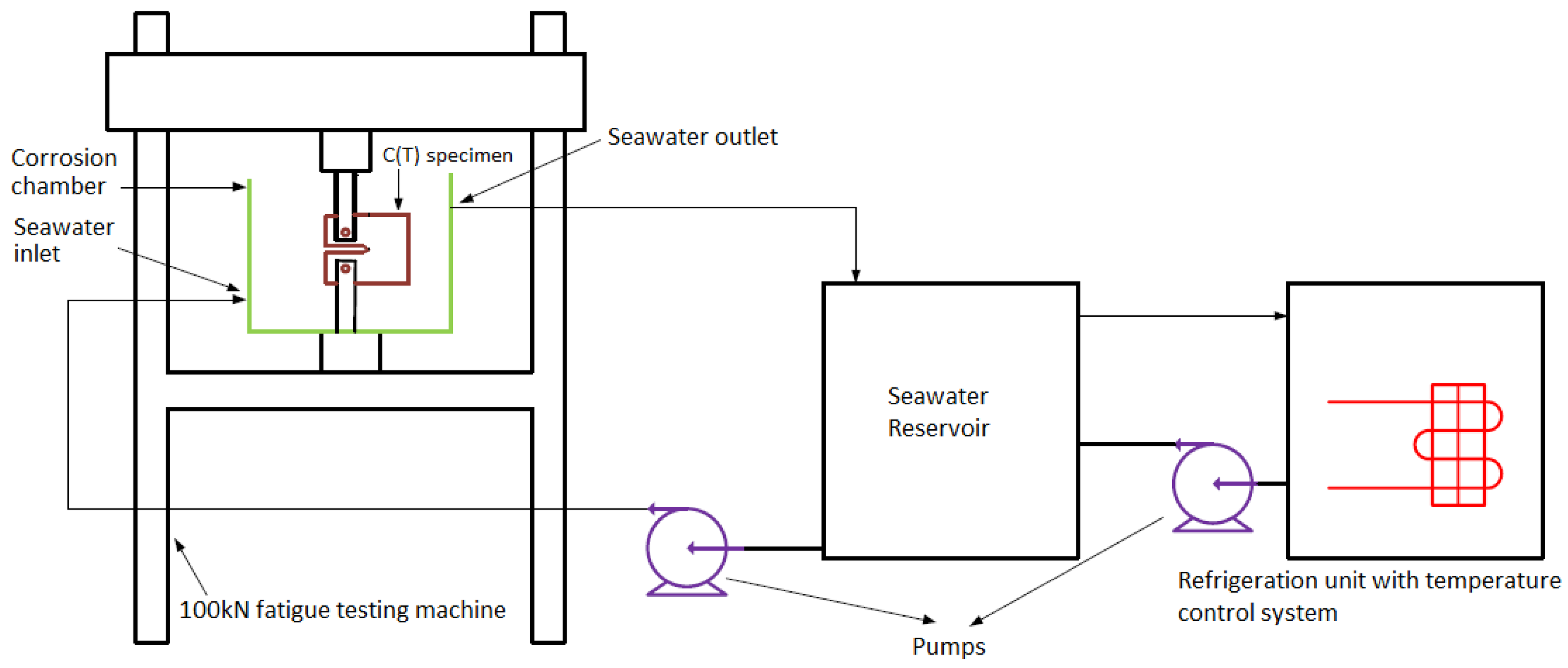

Fig. 4: Corrosion fatigue test rig

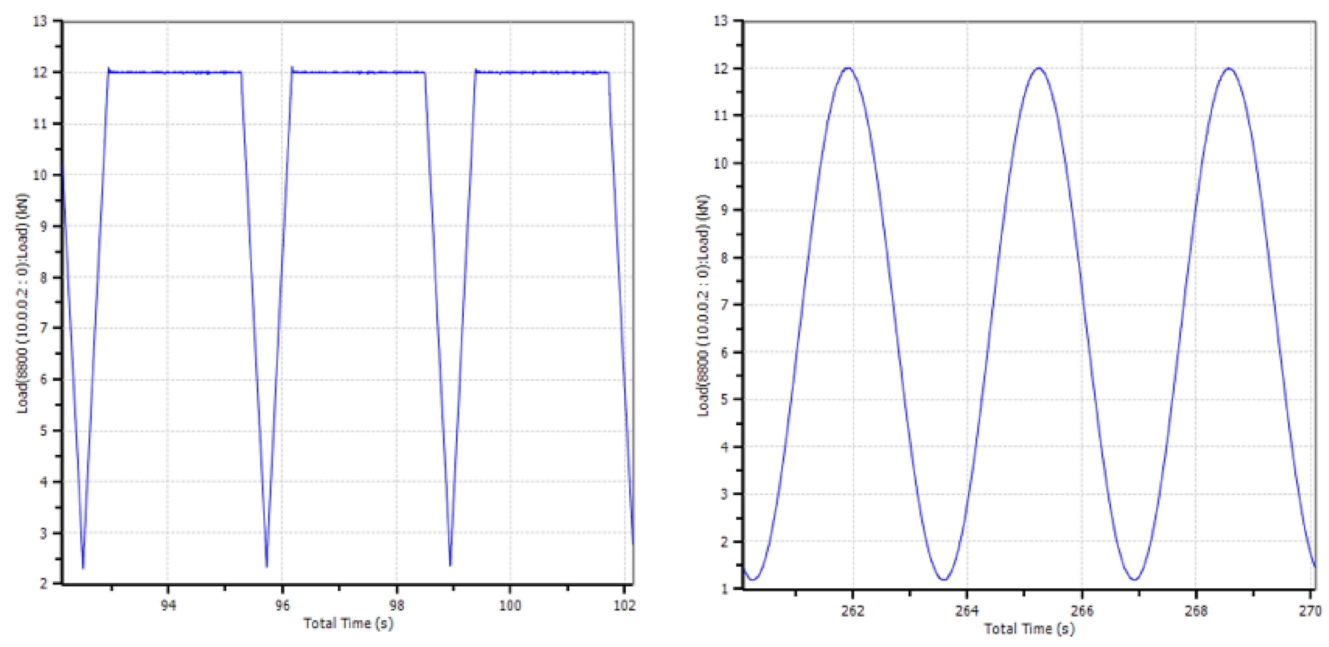

Fig. 5: Holdtime and Sine waveforms for the current study

Preliminary Study Results

For a short duration test a difference in corrosion-fatigue crack growth behaviour of S355G10+M structural steel in seawater has been observed for sine and holdtime waveforms. The crack growth is higher for the holdtime waveform (Fig. 7).

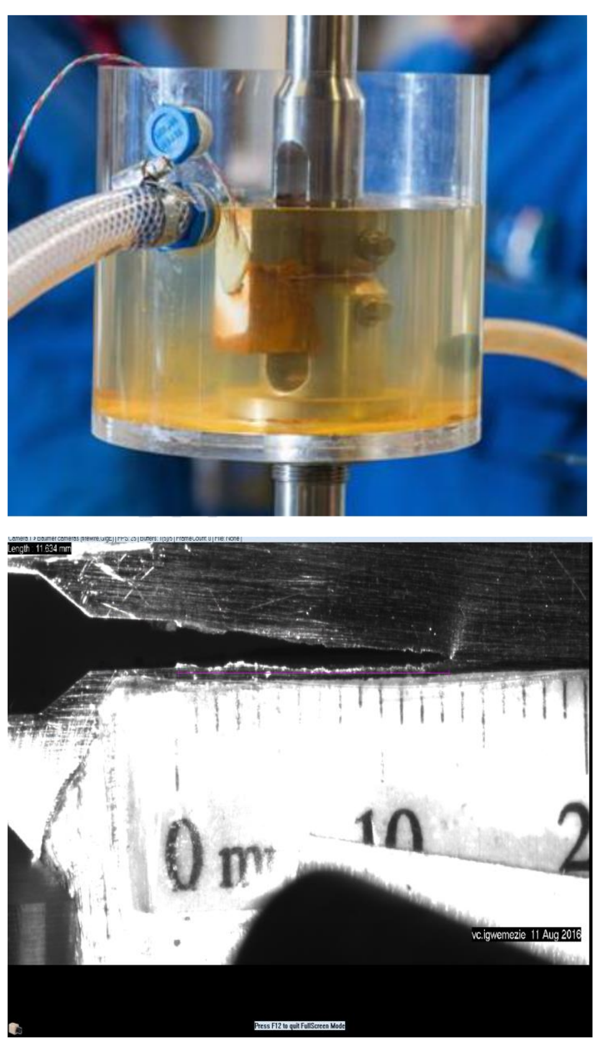

Fig. 6: Seawater test set up and crack growth

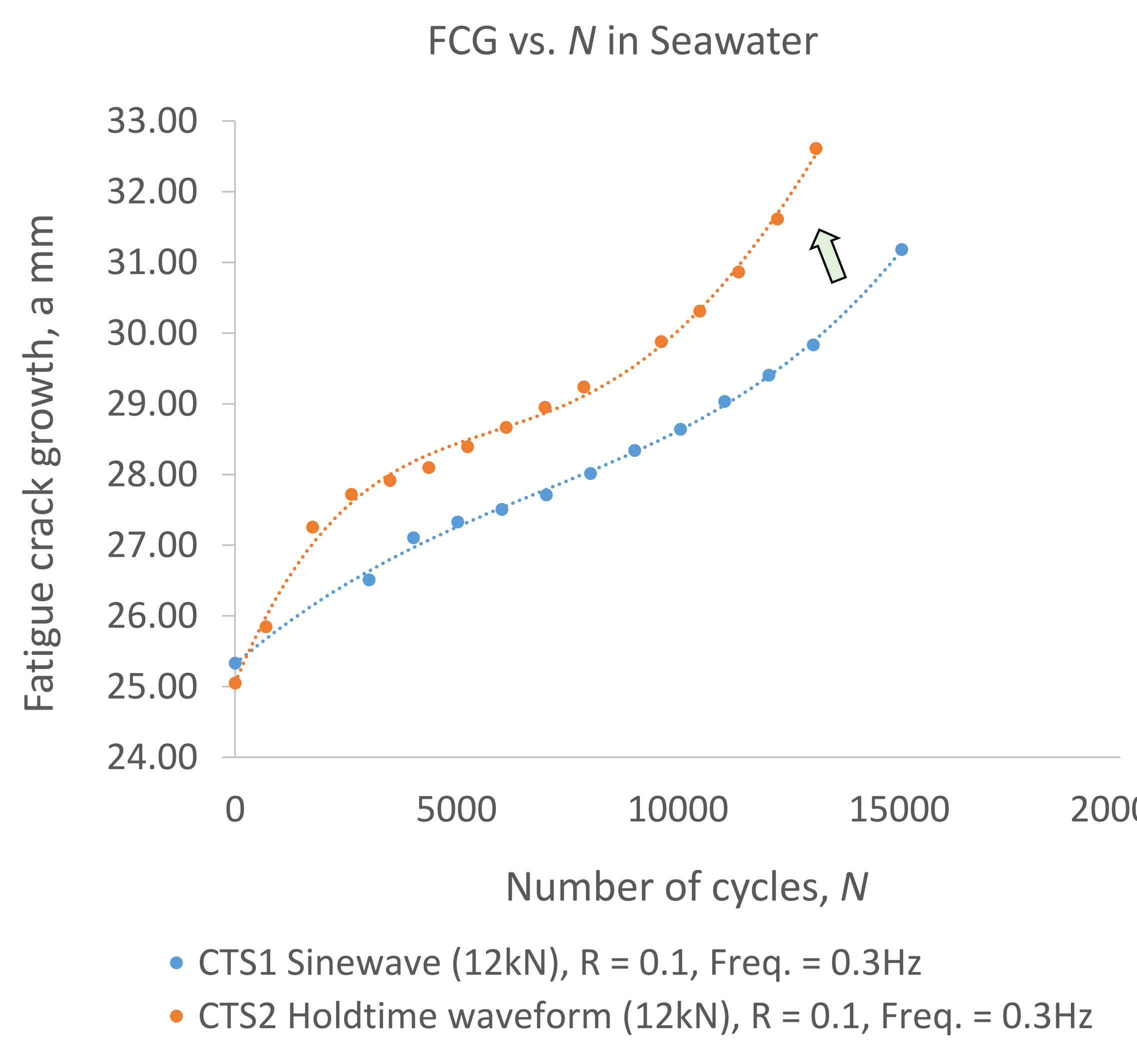

Fig. 7: Plot of CFCG vs. N in seawater for the Sine and Holdtime waveforms

Future Work

1. Determination of long term effect due to seawater, waveforms, frequencies and mean stress for wind turbine support structure
2. Post-Mortem Metallurgical Analyses of failed samples

References
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