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NEPII 計畫成果-整合離岸風機材料與結構之安全性、腐蝕防治及損壞監測研究
NEPII Project-On Safety Analysis, Corrosion Prevention, Damage Monitoring and Detection for Materials and Structures of Offshore Wind Turbines

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摘要

離岸風力發電機位處大海，承受的負荷複雜度大於陸域風機，因此結構及材料問題顯得格外重要。雖然台灣風力充沛，適合發展離岸風力電能，但地震、颱風、洋流、高溫、高濕對於風機結構之強度考驗甚鉅。本研究計畫主要探討離岸風力發電機的結構及材料問題，損傷監測：(1)進行風機葉片光纖光柵損壞監測系統架設與理論分析。(2)探討風機葉片於靜態及動態負載狀態下，光纖光柵損壞監測試驗，研究過程並與電子式應變規(Electrical Strain Gauge, ESG)進行結果比對，確定量測可靠度及準確性，實驗結果得出 FBG 感測器監測與 ESG 感測器結果相當一致，證實布拉格光纖光柵應用於風機葉片損壞監測可行性與準確性。(3)應用無線傳輸於風機葉片損壞監測系統之試驗，透過 Wi-Fi 傳輸技術作資料連結接收，即時監測風力發電機葉片之安全性，並將光纖監測所測得應力及變形結果回饋給風機材料、結構設計端及腐蝕防治，作為日後尺寸設計與參數優化之參考依據，使風機結構達到最佳化。腐蝕防治：(1)針對風機塗層之電化學性質與材料表面分析進行研究，利用恆電位儀分析不同塗層之電化學交流阻抗行為與抗蝕能力表現之評估，最後將兩部分之結果整合，並確立了利用塗層的電化學性質可以有效分析塗層於腐蝕環境中之抗蝕能力與劣化行為之關係。(2)向台電借來商用塗層損傷監測儀(CHM)，透過量測塗層電化學交流阻抗性質之改變來評估塗層受到腐蝕時之劣化行為，雖然 CHM 針對塗層大幅度損傷劣化有優秀之偵測能力，卻無法針對高交流阻抗之風機商用塗層進行量測，原因是風機塗層之高抗蝕性超越了 CHM 之量測極限。(3)針對量測極限進行改良開發，自行研發電路系統腐蝕量測儀(CCS)，經測試確實改善了商用量測儀之極限量測問題，亦可應用於監測風機塗層損傷劣化之系統，後續將與損傷監測共用同樣的數據接收儀器，透過電波遠端傳輸功能將光纖光柵損傷監測與腐蝕監控數據傳回本島，屆時風機的結構設計將會是光纖光柵與塗層腐蝕監控儀架設與分佈位置之關鍵。安全性分析：(1)自行設計 3.6MW、5MW 大型風力發電機葉片，利用分析軟體分析葉片結構共振特性得到受風負載的受力情形，經由研究結果得出自行設計之葉片無共振之疑慮。(2)建立一套風振分析的標準化步驟，並套用至台灣海峽的常態風況及極端風況進行分析，確認葉片若在台灣應用可以確保其安全性。(3)自行建立一套複合材料非平表面建製技術，此技術結合了 Seennamn 真空樹脂灌注成形專利，於製程中加入補強材料，其結果顯示本技術建製的非平表面可以提升複合材料剪切試片強度，未來可將此技術應用至大型風力發電機的翼型尾端膠合處，並結合光纖光柵損壞和腐蝕防治監測之技術，於風機運轉時可進行

即時的損壞監測回報，以延長風機壽命，進而提升風機運轉之效能。

關鍵詞：離岸風力發電、無線傳輸、損壞監測、腐蝕防治、安全性分析

Abstract

Located in waters of the coasts, the offshore wind turbines present technical issues due to demanding climatic and environmental exposures as well as complex dynamic loadings. The structural and material technical issues of the turbine systems is particularly important. Although Taiwan has abundant wind resource that offers a great opportunity for large-scale offshore wind power generation, technical issues of the turbine blades and towers must be taken into serious consideration due to the presence of natural hazards like earthquakes, typhoons, waves and currents, extreme temperature and humidity. In the present study we focus on investigation of structural and material problems of offshore wind turbines. Health Monitoring：(1) The basic theory and technique for FBG sensor damage monitoring system was designed in the first year. (2)The study focuses on the static and dynamic responses monitoring of a scale down V80 wind turbine blade. The study shows that an excellent agreement between the analytical solution and experimental results for deformation monitoring. (3)The damage monitoring technology of wind turbine was developed that utilizes FBG sensors and Wi-Fi wireless communication as timely emergency surveillance system. The results can feedback to the wind turbine design and anticorrosion, this proposed approach provides an effective solution for wind turbine design optimization. Anticorrosion：(1) We focuses on the characteristic of the turbine coatings with its electrode properties and surface properties. We use potentiostat to test the EIS(Electrochemical Impedance Spectrum) of the coatings to evaluate the relationship between corrosion resistance and the impedance, and compare with the two result to establish the connection about EIS and defect. (2)We borrow a commercial corrosion monitor called CHM(Coating Health Monitor) from Taiwan Power Company to research the application on monitoring the coatings of wind turbines in the marine. Although the CHM possess excellent sensitivity to detect the defects of the coatings by using EIS, but it could not measure the impedance of the commercial coatings which have excellent corrosion resistance because the impedance of the commercial coatings are too high for CHM to test. (3)We improve the system on the limit of measuring the impedance of the coatings and we develop a system called CCS (Coating Circuit System) to solve the problem. After experimental, we confirm CCS could measure the higher impedance of the commercial coatings and CCS possess excellent sensitivity to test the defect of the commercial coatings. The data of health monitoring will collect together and transfer to our computers by remote transmission. Therefore, the structural design will influence the layout of corrosion monitor and fiber bragg grating. Safety Analysis：(1)We designed the large wind turbine blade of 3.6MW and 5MW. The blades' resonance characteristic and the reaction force applied by the wind load were analyzed by the finite element analytical software.(2)The standard operating procedure of wind-induced analysis which applied the normal and extreme condition to analyze the blade was set up to make sure the safety when operating.(3)We develop a method to build up a non-flat interface of composite, the Seenamn Composite Resin Infused Molding Process (SCRIMP) was applied to build up the non-flat interface, and the reinforce material was embedded under the fiber. The experimental result suggested that this method could improve the shear strength successfully. In the future, this method could combine with the technic of health monitoring and anticorrosion to lengthen the large wind turbine's operating life.

Keywords: Offshore wind energy; Wireless Communication; Health monitoring; Anticorrosion; Safety Analysis