國立臺灣大學工學院應用力學研究所

碩士論文

Institute of Applied Mechanics

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Master Thesis

摩擦集能元件在旋轉磁激振下的等效參數提取

Parameter Identification of a Triboelectric Generator under Rotary Magnetic Plucking

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中文摘要

本研究主要探討旋轉磁激振式摩擦集能元件（Triboelectric nanogenerator, TENG）的材料參數擷取方法，並應用於能量儲蓄分析以及扭力量測。原理乃利用垂直接觸式摩擦集能元件的 V-Q-X 統御方程式，可獲得等效電路中的等效電壓源和等效電容之等式。接著使用電路模擬軟體 PSpice 來模擬摩擦集能元件之等效電路的電壓輸出。因為外力是以撞擊方式施加，因此在激振產生之間距訊號輸入電路模擬前需進行高斯平滑濾波 (Gaussian smoother) 處理，以消除高頻雜訊來避免模擬電壓訊號失真，研究結果顯示：我們利用提出的旋轉磁激振式摩擦集能方法能夠從旋轉機構擷取動能並產生電壓訊號，並且利用電路模擬和實驗量測所得的輸出電壓波形，透過曲線擬合方法來提取材料參數，也驗證了此方法在不同激振頻率下的適用性。這種參數提取方法能夠簡化實驗量測流程，只需要進行間距訊號的量測，並結合已知參數作為電路模擬的輸入，結合整流電路可進行能量儲蓄分析。最後，利用摩擦集能元件對接觸面積變化有高靈敏度的特性，我們可以用提取的有效接觸面積作為扭力感測器的扭力監測參考依據。

關鍵字：摩擦集能元件；能源擷取；旋轉磁激振；等效電路模型；訊號濾波；參數提取；扭力感測

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ABSTRACT

The thesis proposes a novel method for parameter identification of a triboelectric nanogenerator (TENG) under rotary magnetic plucking, with potential applications in energy harvesting and torque sensing. The equivalent circuit model is constructed using the standard V-Q-X relationship that characterizes a vertically contacted TENG. This model comprises an equivalent voltage source in series with an equivalent varying capacitance. However, the involvement of high-frequency noise and signal distortion arising from the magnetic impulsive plucking poses a challenge. To address this issue, the study employs a Gaussian smoother to preprocess the input excitation signal before conducting PSpice circuit simulations to analyze the output voltage. The research presents two significant findings. Firstly, experimental results demonstrate the generation of output voltage when the TENG is periodically plucked by a rotating magnet. Secondly, parameter identification is achieved by measuring the separation distance between the two triboelectric charged layers. The study successfully determines key parameters, including the triboelectric charge density, the effective thickness of the dielectric layer, and the effective contact surface, through a meticulous comparison between the simulated voltage and the measured voltage. These parameters provide a foundation for performance evaluation of energy harvesting, including the inclusion of a rectification circuit. Moreover, the study proposes a prototype of a torque sensor by numerically evaluating the effective contact surface.

Keywords: Triboelectric nanogenerator (TENG), Energy harvesting, Rotary magnetic plucking, Equivalent circuit model, Signal filtering, Parameter identification, Torque sensing

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