Pumping Cycle Based on Elastic Tether

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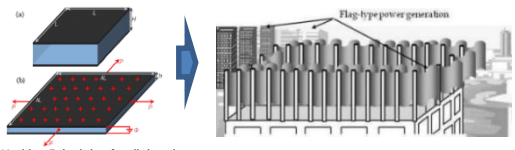
(**Abstract**) This work is focused on a Pumping Cycle (PC) of Airborne Wind Energy System (AWES) concept for adopting Dielectric Elastomer Generator (DEG) for Power-Take-Off (PTO) since a wind powered generation concept based on fluttering flag made of Electro-Active Artificial Muscle appeared [1]. Reeling in the recovery phase is inherently required for a pumping AWES owing to the maximal tether length. To address this issue, a rubbery tether is applied for PC. Traction power to be generated in the traction phase is transferred to the rubbery tether and stored as tension power there. At the end of traction phase, a depowered kite is pulled towards ground station by the tension power stored in the rubbery tether, resulting in less reeling and noise. Such PC can be applicable for an AWES at Demilitarized Zone (DMZ) or close to city. The main features of the PC are as follow: (1) traction power is stored as tension power in an elastic tether, (2) output power is generated for recovery phase if an elastomeric tether made of DEG is configured for PTO, and (3) Energy Harvesting Cycle (EHC) of a DE [2] for (2) depends the PC and can be optimized by kite control. A hand-made toy kite system was used to observe the PC, as limited to validate only the PC concept. Thus, an engineered prototype of an AWES is further required to reveal some problems such as automatic control including takeoff and landing, efficiency in energy conversion, continuous power generation, selection of DE materials, etc.

1. Motivation

1. Deformable polymer technology

   Chiba, et al. at SRI has proposed a wind powered generation concept based on a deformable polymer [1] and Generator mode of dielectric elastomer (DE) is introduced in [2][3].



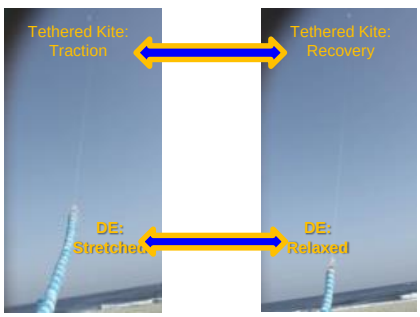
Working Principle of a dielectric elastomer transducer, stretched [(a)→(b)] by kinetic energy and relaxed [(b)→(a)] at constant DE volume. (Figure: adapted in [3])

2. Problem definition

   Recovery and tether reeling of pumping AWES results in noise and needs an improvement or alternative solution in order to deploy a pumping AWES at DMZ or close to city.

3. Results

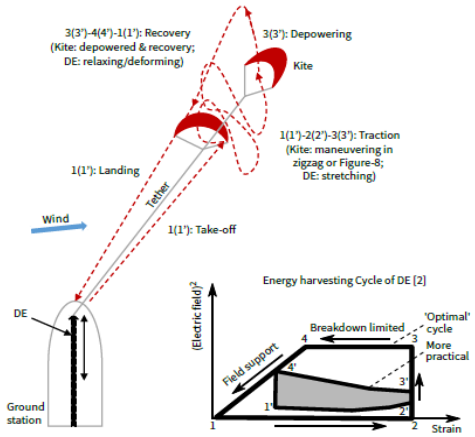
1. At constant wind speed, a cyclic pumping was observed with an elastic tether made of 3M VHB tape, without any control and tether reeling.
2. Such cyclic pumping was also observed with an off-the-shelf polyurethane tether (5 mm diameter and 50 m long) made in Germany, at constant wind speed.
3. The cyclic pumping was also observed in two-line tethering and with 3 stacked toy kites, at constant wind speed.



2. Approach

A pumping AWES concept is assumed as figured in the below and a DE generator (DEG) in bi-directional actuation is also assumed on ground station. In addition, a single-mode motor and pulley systems are assumed for steering on ground station.

1. Tension power stored in elastic tether (typically, DE membrane) during traction phase is consumed for recovery of a tethered pumping wing, resulting in less noise and less tether reeling.
2. Pumping cycle and control is optimized on working cycle of elastic tether.
3. characteristic features of a pumping cycle based on elastic tether (for example, natural rubber, 3M VHB tape, polyurethane, etc.) are observed. (Note) Owing to the lack of any AWE tool and man-power, this work was limited to validate only the PC concept.



4. Summary

Only the pumping cycle (PC) concept was positively observed though well-designed engineering, any experimental facility and supported tools couldn't be used. The PC can be applied for a pumping AWES at DMZ or close to city. The limited PC results shall be expanded with an engineered AWES prototype, in order to apply it for a real pumping AWES, together with further works including:

(1) automatic control including take-off & landing, cross wind power and fast recovery,
(2) efficiency in energy conversion,
(3) continuous power generation,
(4) selection of DE materials,
(5) system design, and so on.

References

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[2] Perline R., Prahlad H.: Generator Mode – Devices and Applications. In: Carpi, F. et al. (eds.) Dielectric Elastomers as Electromechanical Transducers, Chap. 15, Elsevier (2007)

[3] Soo Jin Adrian Koh, et al.: Dielectric Elastomer Generators: How Much Energy Can Be Converted. IEEE/ASME Tr. Mechatronics, Vol. 16, no. 1 (2011)

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