TRIBO-ELECTRIC POWER GENERATING BEHAVIOR OF TEXTILE FLOCKED SURFACES

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ABSTRACT

Tribo-electrically diverse flocked fiber surfaces have been found to reliably generate respectable triboelectric energy signals. This technology has been named Flocked Surface Triboelectric (power) Generation (FSTG). By mechanically contacting [nylon fiber///polyester fiber] flocked surfaces, electrical power levels of up to 6 nano-watts/cm^2 are easily generated. An apparatus has been constructed to systematically determine FSTG power levels generated by contacting/separating aluminum sheet-backed flocked panel surfaces at various contact/separation rates (Contacts Per Minute-CPM). Measurements show that power levels sharply increase at CPM rates below 120. Work is now in progress to significantly increase the power output level of these FSTG systems.

Key words: flocked surfaces, triboelectricity, power generation, energy conversion

1. INTRODUCTION

The phenomena of triboelectricity has been around for since ancient times. Only recently has the phenomenon been seriously studied as a practical means of converting mechanical energy (frictional contact between tribo-electrically diverse surfaces) into useful electric power. These efforts have been ably spearheaded by Wang at Georgia Tech [1][2][3]. Many types of surfaces exist and have been evaluated as triboelectric couplings these have been rated according to what is called a tribo-electric series as briefly denoted in Table 1. This is a well known and studied series where materials are rated according to whether they attract of repel electrons when they are rubbed together. In terms of textile fibers, Table 1 shows that nylon and polyester fibers are far apart in this triboelectric series and should prove to be a good material tribo-coupling for generating electric charge. To this end, as UMass Dartmouth has been in the forefront of textile flock processing technology for many years, it was deemed relevant to determine if the frictional contact of a nylon fiber flocked surface and a polyester fiber flocked surface could indeed be combined to from effective tribo-electric power generating surfaces. Preliminary studies implementing this idea were soon carried out showing that tribo-charges could easily be generated by meshing together (face-to-face contact/separation) nylon and polyester flocked fiber surfaces. From these preliminary discovery experiments, it was hypothesized that these flocked surface tribo-effects were most likely caused by the inherently high surface area of flocked surfaces coupled with the large number of fiber ends that characterize all flocked surfaces. Fiber ends could indeed serve as charge accumulation sites for the frictionally generated electrons. This paper presents the result of experimental efforts to more fully evaluate the observed generation of triboelectric charges by interacting flocked surfaces. This UMass Dartmouth materials technology has suitably named this technology by the acronym FSTG for Flocked Surface Triboelectric (power) Generation.

Table 1. Abbreviated Triboelectric series

Polyurethane Foam	Positive (+)
Nylon	
Silk	
Aluminum	
Steel	
Amber	
Nickel	
Copper	
Polystyrene	
Polyester	
Polyimide	Negative (-)
Polytetrafluoroethylene (PTFE)	

2. EXPERIMENTAL MATERIALS AND METHODOLOGY

2.1 Contact/Separation Apparatus: While initial experiments were conducted using a human hand induced contact///separation motion of the flocked surfaces, it was soon realized that a more "controlled" experimental apparatus was needed in these experiments. In response, a special apparatus was designed and constructed to controllably intermesh-contact and separate two 10 cm x 10 cm (4" x 4") flocked surfaces at a given constant contact frequency (Contacts Per Minute -CPM). This apparatus (Figure 1) is referred to as the Flock Surface Controlled Contactor (FSCC) device. This apparatus is able to contact/separate flocked surfaces at a pre-set contact frequency and inter-mesh penetration depth. Coupled to this FSCC device was an electronic signal conditioning circuit. Earlier it was learned that the output electrical signal generated by FSTG systems are an AC voltage accompanied by a small AC current. Therefore, these generated FSTG signals were first electronically rectified to a DC voltage. The generated voltage was subsequently stored in the capacitor unit of a simple RC circuit. In this set-up, the power signal data was acquired by digital oscilloscope and LabVIEW® system.

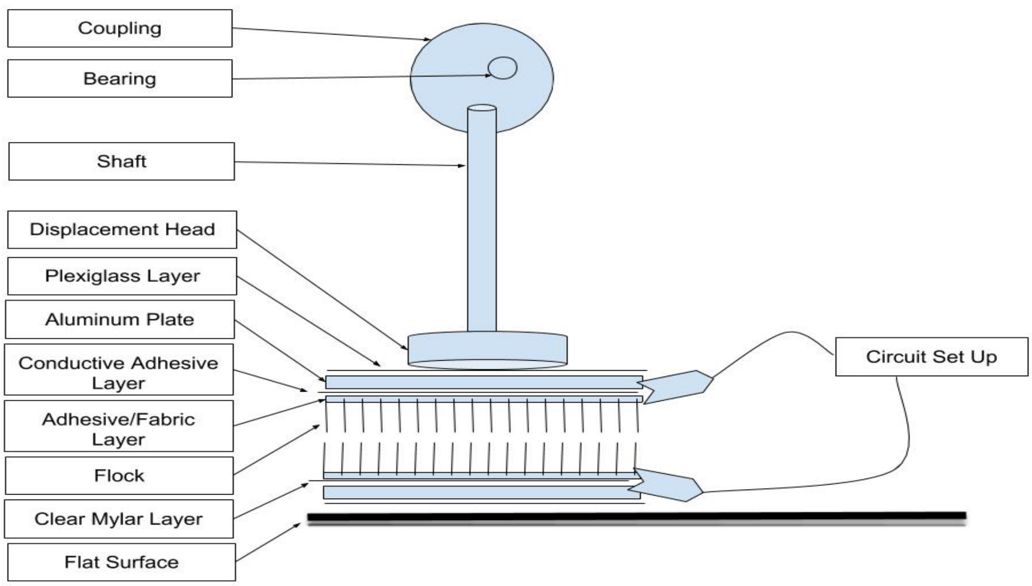

Figure 1: Schematic of FSTG Panel Contact/Separation Testing Apparatus

2.2 Tribo-Couple Panel Details: The basic embodiment of the FSTG concept is sketched in Figure 2. This Figure also shows the essential geometric test ssample set-up that was used in the FSCC testing apparatus. In this set-up, tribo-charges of up to 5 volts (DC) could be routinely generated using a series of nylon/PET flocked fiber layer systems.

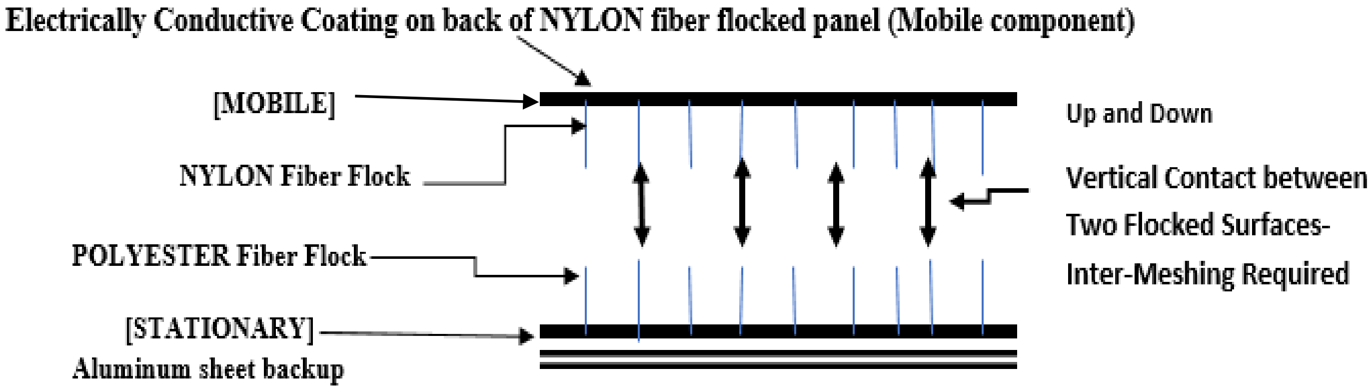

Figure 2: Sketch of a Striking Flocked Surface Triboelectric Power Generator (FSTG)

2.2 Materials: All flocked fiber materials were either 45 denier, 2 mm long or 20 denier, 2 mm long nylon 66 (Ny) or polyester (PET) supplied courtesy of Specro Coatings, Inc., Leominster, MA. The coupling configurations are presented in the Figure 3 "key-designations" where the added notations are the flocked surface's flock density (fibers/mm^2). All data obtained was as average of at least five (5) determinations.

3. RESULTS

Using the FSCC apparatus, a series of FSTG data for nylon fiber///polyester fiber flocked surfaces was obtained. The results summarized in Figure 3 clearly show that the power generated from the flocked fiber surfaced tribo-couplings sharply increases for at contact/separtion rates below 120 CPM. Also notable is that the power output for all these tribo-systems are in the nano-watt (10^{-9}) /cm^2 range. The highest power value registered was about 5.4 x 10^{-9}/cm^2 for the flocked PET45-30, Nylon45-54 system. These power output values are by no means considered the optimum achievable tribo-power values for FSTG systems. It is believed that by discretely selecting tribo-fiber material types, configured in a more electronically designed sample/material system, that power values in the milli-watt/cm^2 range can be easily generated. This is the goal of future experimentation.

4. DISCUSSION

The FSTG data presented are considered preliminary. From the outset, flocked surfaces are indeed "commodity" materials. They are low cost and could easily be configured into a large area contact/separation mode system that is designed into creating high output power mechanical-to-electrical energy transducer. FSTG elements can potentially be fabricated into 70-inch wide web-forms as roll-to roll goods by the commercial standard textile flocking processors. Once an optimized FSTG prototype of high power-output is established, the commercialization and scale-up into large-scale FSTG employing clean energy applications that require higher power output will be pursued. Additionally, FSTG triboelectric generators can be considered as a more robust and reliable mechanical to electrical power generator compared to existing tribo-couple film materials. It is envisioned that FSTG systems could be readily adaptable to ocean wave energy harnessing applications [1].

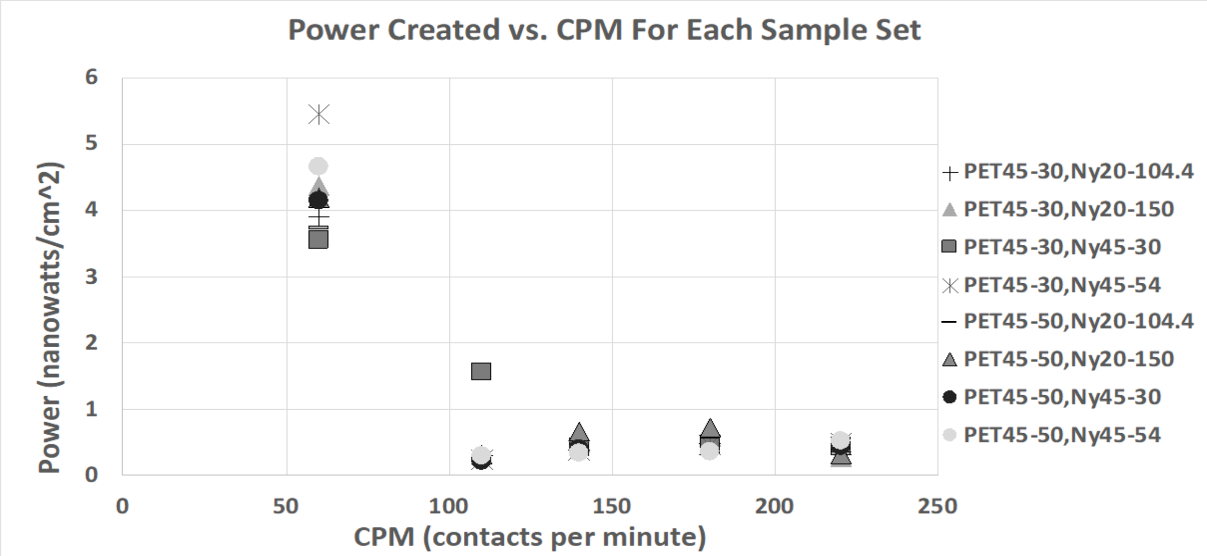

Figure 3: Power Generated from the Contact/Separation Action of Two Tribo-matched Flocked Fiber Tribo-couplings as a Function of Contact/Separation Rate (CPM).

5. CONCLUSIONS

In this paper, studies on the effect of fiber geometry (denier and length) and flock density (number of fibers /mm^2) have been carried out, which show that overall, the tribo-couplings composed of the higher denier flock fibers (45 denier) produced slightly higher tribo-power values compared to the lower denier tribo-couplings (20 denier) (see Figure 3). Work in now in progress to significantly increase the power output of flocked surface tribo-couplings employing polyimide fiber as one of the flocked surfaces. Other triboelectrically diverse fiber type flocked surface tribo-couplings are also being evaluated in ongoing studies. Our goal is to develop FSTG systems that will deliver electrical power into the milli-watt and watt range and higher by increasing surface area and fiber types and geometry. Once this is accomplished, the developed FSTG modular units are expected to be applicable to wearable biomedical body sensor networks, smart and sustainable mechanical to electrical energy conversion device for powering radio frequency personal identification devices and remote health monitoring electronics. Combining FSTG modular power generators with LEDs would also enable these flocked surface triboelectric power generators to be used in self-sustaining walkway lighting systems.

6. ACKNOWLEDGEMENTS

The authors wish to thank the UMass Dartmouth Bioengineering Department for providing funds to carry out this feasibility study. We also thank Mr. Raj Shah, President of Spectro Coatings for supplying the flock fiber material used in this study.

7. REFERENCES

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