EGTRIB Journal
JOURNAL OF
THE EGYPTIAN SOCIETY OF TRIBOLOGY
VOLUME 19, No. 3, July 2022, pp. 10 - 18 **ISSN 2090 - 5882**
(Received May 09. 2022, Accepted in final form June 17. 2022) **www.egtribjournal.com**

VOLTAGE GENERATED FROM TRIBOELECTRIFICATION OF RABBIT FUR AND POLYMERIC MATERIALS

Ali A. S.[1], Al-Kabbany A. M.[2] and Ali W. Y.[2]

[1]Mechanical Power Engineering Dept., Faculty of Engineering, Suez Canal University, EGYPT.
[2]Department of Production Engineering and Mechanical Design, Faculty of Engineering, Minia University.

ABSTRACT

Triboelectric Nanogenerators are emerging technology with huge potential in a variety of fields, from green energy to self-powered sensors. They are the products of triboelectrification which causes a generation of electrostatic charges on any two surfaces that come into contact with one another. This study aims at investigating the behavior of the voltage output of many different triboelectric nanogenerators with load, in both contact and separation as well as sliding.

It was found that, when the applied load on a TENG increases, the generated voltage increases linearly. The generated voltage at sliding was higher than that generated in contact and separation. Besides, rough contact surfaces generated relatively higher voltage especially at contact and separation due to the increase of the contact area subjected to friction.

KEYWORDS

Voltage, triboelectrification, contact and separation, sliding, rabbit fur, polypropylene, polytetrafluoroethylene, Kapton.

INTRODUCTION

It is well known that when two materials come into contact with one another, electric charges of equal but opposite values accumulate on each surface. This phenomenon is known as triboelectrification, [1 - 4]. Since triboelectrification is such a widespread phenomenon, reducing it when necessary is important, as it is hypothesized that electrostatic charges (ESC) can accelerate the growth of cancer cells, [5] and can cause fires, [6, 7], research was done to try to find ways to reduce the electrostatic charge generated by different textiles, like reducing the charge generated by polyester, [8], artificial turf, [9], and floors, [10]. It is not essential that in all circumstances, low ESC is desirable, for example, it is thought that masks and medical equipment can resist viruses like Covid-19 better if they have a negative charge generated on their surfaces, [11 - 14].

In order to predict the amount and type of charge generated on each surface when two surfaces come into contact, the triboelectric series was developed, [15 - 17]. It ranks materials by their likelihood of acquiring a positive charge when they come into contact with another

material. Thus, materials lower in the series are more likely to obtain a negative charge, in the triboelectric series, where polytetrafluoroethylene (PTFE), polypropylene (PP) and Kapton lie close to the bottom of the series, while rabbit fur lies close to the top of the series, [18].

Triboelectrification was recently used as a source of clean energy. If metal electrodes were placed on one surface of two different materials that are on the opposite ends of the triboelectric series, and the two materials were then forced to come into contact with one another, a potential difference will generate between the two electrodes due to the different charges that accumulate on both of them. If the two electrodes were shorted, a small current will pass between them, before an equilibrium state is reached. This device is known as a triboelectric nanogenerator (TENG). The TENG can be used in energy generation, [19 - 22] and self-powered sensors, [23 - 26]. The output voltage of a TENG can be predicted using the V-Q-x equation, [27].

Previous work has been done to obtain a relationship between the applied force on a TENG and its output voltage in contact and separation mode, it was found that in most cases, the voltage rises rapidly at first, then the rate of increase of voltage with force starts to decrease and the relationship becomes more and more linear, [28 - 30].

The present study aims to investigate the voltage generated from contact and separation as well as sliding of rabbit fur and polymeric materials.

EXPERIMENTAL

Eight different TENG terminals were made of aluminum foil adhered to the tested contact surfaces by a thin layer of double-face adhesive. The dielectrics used were rabbit fur, PP, PTFE and Kapton. The rabbit fur was adhered to a wooden cube of 40 × 40 ×40 mm^3, while the polymeric materials PP, PTFE and Kapton in the form of tape were adhered to a polymeric base. Both rubber fur and polymeric tapes were fitted by an aluminum sheet of 0.25 mm thickness to be used as terminals to measure the generated voltage resulting from contact and separation as well as sliding.

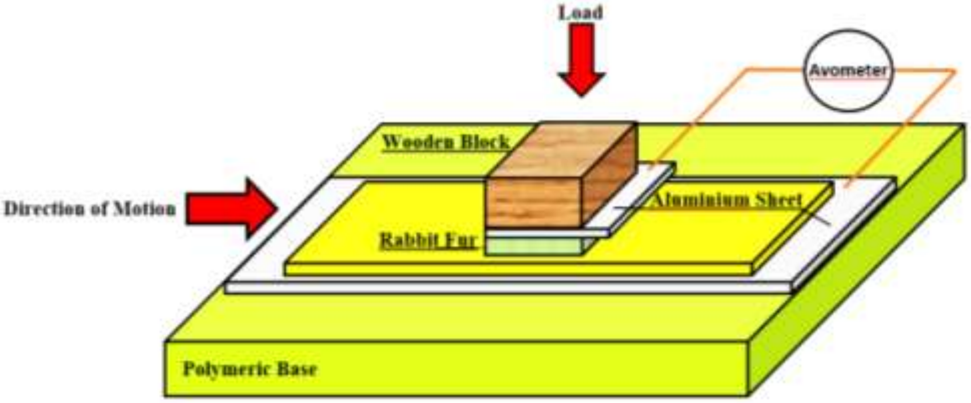

Fig. 1 The measuring procedure.

Fig. 2 Rabbit Fur.

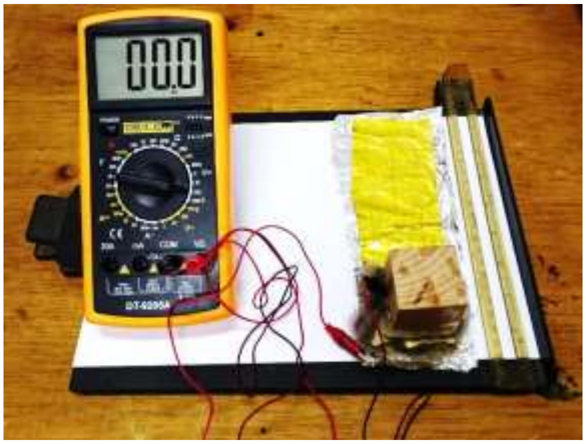

Fig. 3 Rabbit fur sliding on Kapton.

Fig. 4 PTFE counterface.

The tested different dielectrics were pressed against each other under load varying from 3.3 to 20.5 N and separated. Then the voltage between the two aluminum foil electrodes was measured using a voltmeter. This process was repeated 10 times for every load value for

every pair of dielectrics, and the average voltage values were calculated. The details of the measuring procedure and materials are shown in Figs. 1 – 4. During sliding the rabbit fur was slid along the length of 200 mm of the polymeric tapes and the voltage after separation was measured using a voltmeter.

RESULTS AND DISCUSSION

The results of this experiment are shown in Fig. 5 – 9, where the voltage generated from contact and separation as well as sliding of the tested materials is illustrated. As for rabbit fur and Kapton, Fig. 5, voltage significantly increased with increasing normal load at contact and separation as well as sliding. It can be noticed that the relationship between the normal load and the voltage is linear, however, this seems to contradict the previous results, [30], which describe the relationship between voltage and load as rapid rising at first, and then later plateauing and approaching a linear relationship after crossing a specific threshold. However, considering that those experiments were done at higher loads than the ones at which the threshold mostly exists. The linear relationship can be useful in most applications. Sliding of the tested specimens, the voltage generated was relatively higher than the voltage generated in contact and separation. The values of the voltage at 20.5 N load were 1200 and 300 mV at sliding as well as contact and separation respectively.

The voltage generated from contact and separation as well as sliding of rabbit fur on PP, Fig. 6, significantly increased up to values higher than that observed for rabbit fur/Kapton. This behavior was expected due to the location of PP and rabbit fur in the triboelectric series. Further voltage increase was observed for the pair of rabbit fur/PTFE, Fig. 7, where the highest values were approximately 3000 and 4000 mV at contact and separation as well as sliding respectively. This observation can recommend those materials to be applied in TENG development.

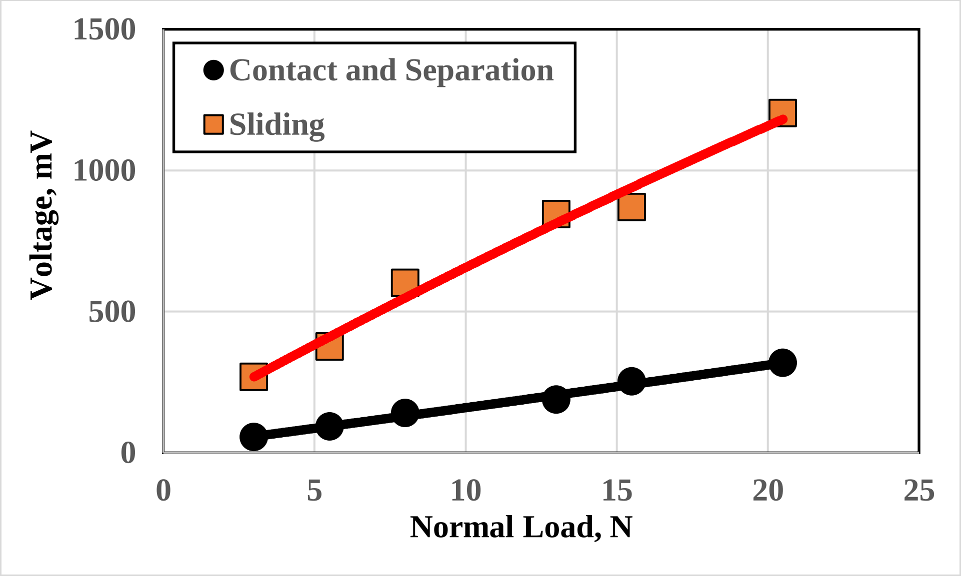

Fig. 5 Voltage generated from contact and separation as well as sliding of rabbit fur on Kapton.

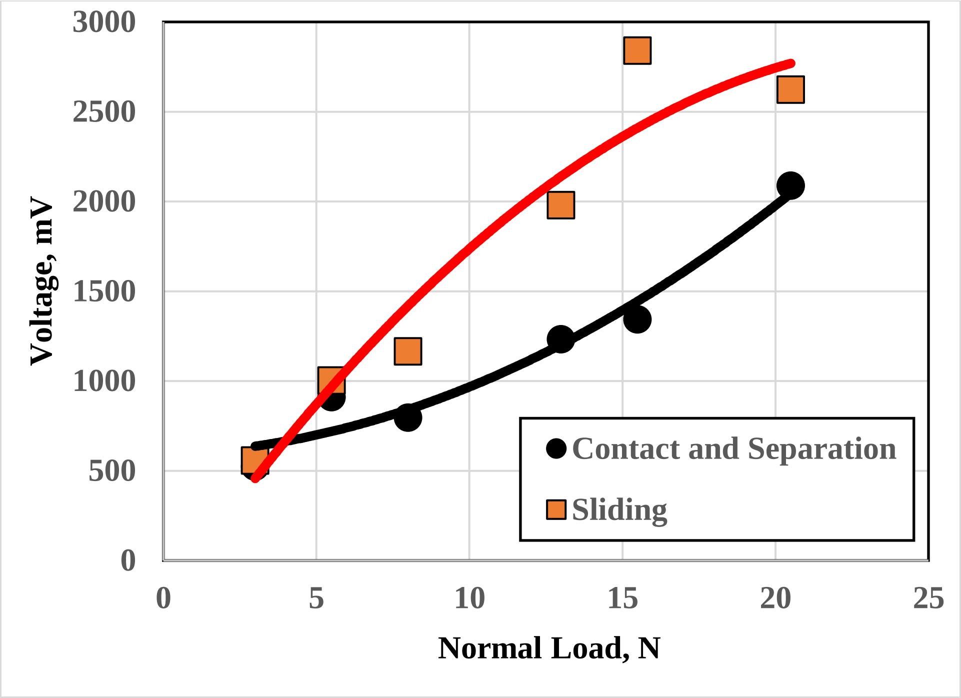

Fig. 6 Voltage generated from contact and separation as well as sliding of rabbit fur on PP.

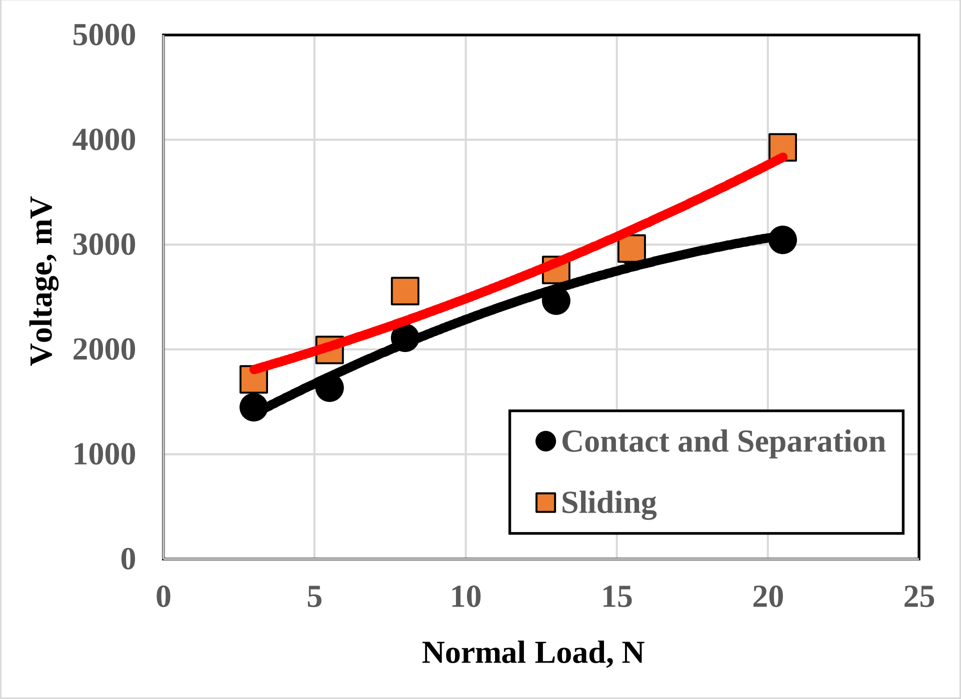

Fig. 7 Voltage generated from contact and separation as well as sliding of rabbit fur on smooth surface of PTFE.

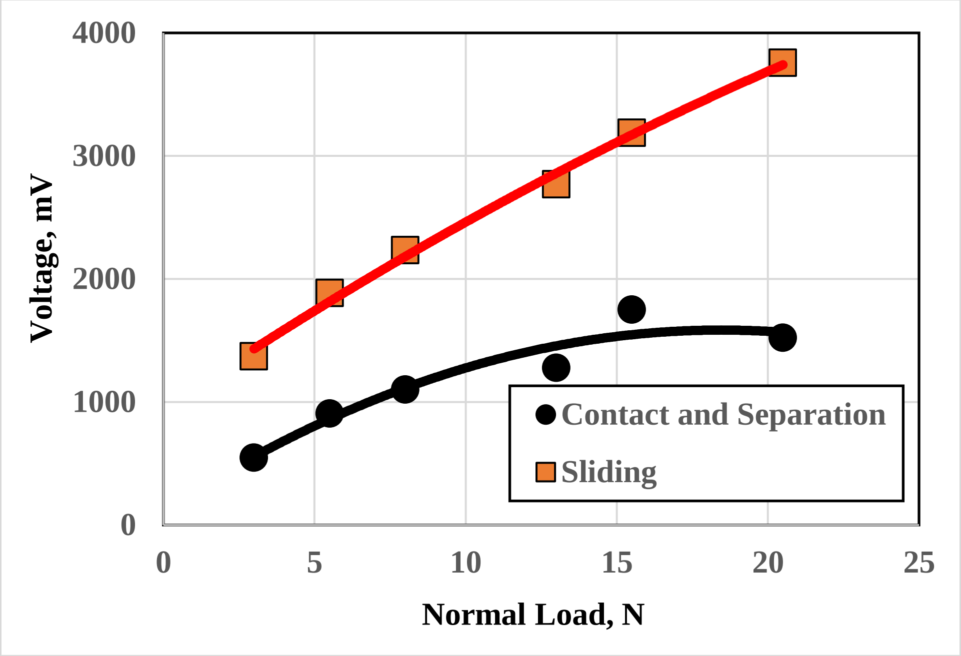

Fig. 8 Voltage generated from contact and separation as well as sliding of rabbit fur on roughened surface of PTFE by emery paper of 60 grit.

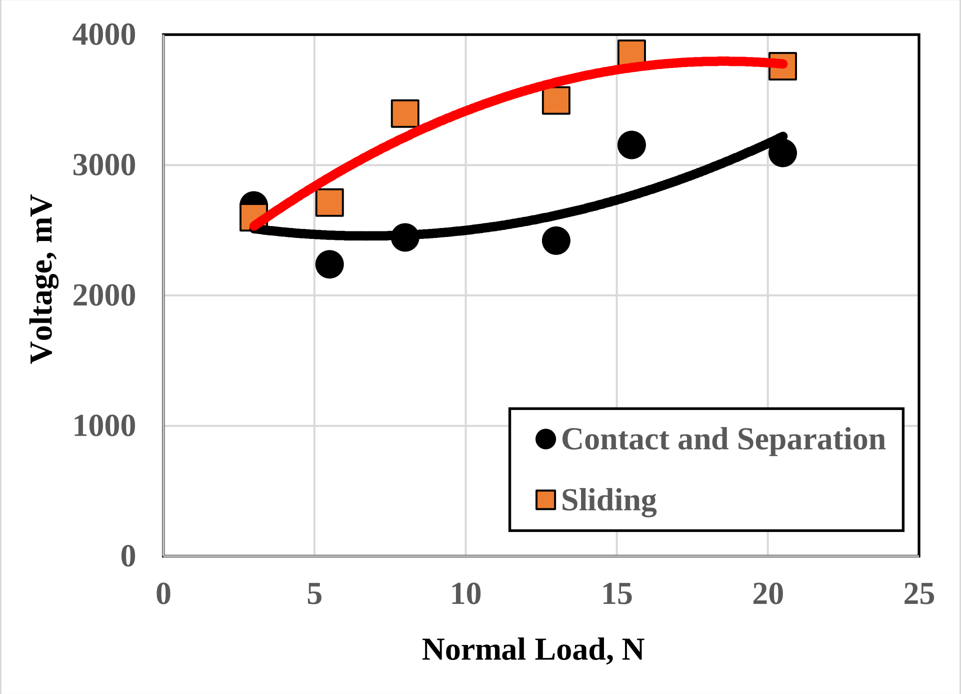

Fig. 9 Voltage generated from contact and separation as well as sliding of rabbit fur on roughened surface of PTFE by emery paper of 120 grit.

Further experiments were carried out to investigate the influence of the surface texture on the voltage generated from TENG. PTFE film was adhered by emery paper of 60 and 120

grit as substrates, Figs. 8 and 9. It was noticed that the roughened PTFE by 120 grit generated relatively higher voltage than that measured for 60 grit. That is clearly shown at contact and separation. It seems that as the number of asperities of the contacting surfaces increases the ESC increases. This can be attributed to the increase of the contact area of PTFE subjected to the friction of the fur fibers.

CONCLUSIONS

1. As the applied load on a TENG increases, the generated voltage increases.
2. At the load range tested in this experiment, voltage increases linearly with load.
3. At sliding, the generated voltage was higher than that generated in contact and separation.
4. Increasing the number of asperities of the contacting surfaces increases the generated voltage.

REFERENCES

1. Al-Qaham, Y., Mohamed M. K., and Ali. W. Y., "Electric Static Charge Generated From the Friction of Textiles", Journal of the Egyptian Society of Tribology, EGTRIB, Vol. 10, No. 2, pp. 45 - 56, (2013).
2. Shivangi N., Mukherjee R., and Chaudhuri B., "Triboelectrification: A review of experimental and mechanistic modeling approaches with a special focus on pharmaceutical powders", International journal of pharmaceutics Vol. 510, No. 1, pp. 375-385, (2016).
3. Ali A. S., "Triboelectrification of Synthetic Strings", Journal of the Egyptian Society of Tribology, EGTRIB, Vol. 16, No. 2, pp. 26-36, (2019).
4. Pan S. and Zhang Z., “Fundamental theories and basic principles of triboelectric effect: a review” Friction, Vol. 7, No. 1, pp. 2-17, (2019).
5. Gary J. R., Frith C. H., and Parker D. J., "Cancer Growth Acceleration by External Electrostatic Fields", Proceedings of the Electrostatics Society of America Annual Conference, (2004).
6. Gabor D., Radu S. M., Ghicioi E., Părăian M., Jurca A. M., Vătavu N., Păun F. and Popa C. M., "Study of methods for assessment of the ignition risk of dust/air explosive atmospheres by electrostatic discharge", Calitatea, Vol. 20, No. S1, pp. 93, (2019).
7. Glor, M., and Thurnherr P., "Ignition Hazards Caused by Electrostatic Charges in Industrial Processes", Thuba Ltd, (2015).
8. Al-Kabbany A. M., and Ali W. Y., "Reducing the electrostatic charge of polyester by blending by polyamide strings", Journal of the Egyptian Society of Tribology, Vol. 16, No. 4, pp. 36-44, (2019).
9. Ali A.S., Al-Kabbany A. M., Ali W. Y. and Samy A. M., "Reducing the electrostatic charge generated from sliding of rubber on polyethylene artificial turf", Journal of the Egyptian Society of Tribology, Vol. 17, No. 2, pp. 40-49, (2020).
10. AlOtaiby A., Elhabib O. A. and Ali W. Y., "Reducing Electric Static Charge Generated from Epoxy Flooring Materials", Journal of the Egyptian Society of Tribology, EGTRIB, Vol. 11, No. 4, pp. 25 - 35, (2014).
11. Ali A.S., Al-Kabbany A. M., Ali W. Y. and Badran A. H., "Triboelectrified Materials of Facemask to Resist Covid-19", Journal of the Egyptian Society of Tribology, Vol. 18, No. 1, pp. 51-62, (2021).

12. Ali, A.S., Al-Kabbany A. M., Ali W. Y. and Ibrahem R. A., "Proper Material Selection of Medical Safety Goggles", Journal of the Egyptian Society of Tribology, Vol. 18, No. 2, pp. 1-15, (2021).
13. Al-Kabbany A. M., Ali W. Y., and Ali A. S., "Proposed Materials for Face Masks", Journal of the Egyptian Society of Tribology, Vol. 18, No. 3, pp. 35-41, (2021).
14. Al-Kabbany A. M., Ali W. Y., and Ali A. S., "Proper Selection Materials of Face Shields, Eyeglasses and Goggles", Journal of the Egyptian Society of Tribology, Vol. 18, No. 3, pp. 42-51, (2021).
15. Zou H., Zhang Y., Guo L., Wang P., He X., Dai G., Zheng H., Chen C., Wang A. C., Xu C. and Wang Z. L., "Quantifying the triboelectric series", Nature communications, Vol. 10, No. 1, pp. 1427, (2019).
16. Diaz, A. F., and Felix-Navarro R. M., "A semi-quantitative tribo-electric series for polymeric materials: the influence of chemical structure and properties", Journal of Electrostatics, Vol. 62, No. 4, pp. 277-290, (2004).
17. Burgo, Thiago AL, Galembeck F., and Pollack G. H., "Where is water in the triboelectric series?", Journal of Electrostatics Vol. 80, pp. 30 - 33, (2016).
18. Han J., Feng Y., Chen P., Liang X., Pang H., Jiang T. and Wang Z. L., "Wind-driven soft-contact rotary triboelectric nanogenerator based on rabbit fur with high performance and durability for smart farming", Advanced Functional Materials, Vol. 32, No. 2, p. 2108580, (2022).
19. Yang Y., Zhu G., Zhang H., Chen J., Zhong X., Lin Z. H., Su Y., Bai P., Wen X. and Wang Z. L., "Triboelectric nanogenerator for harvesting wind energy and as self-powered wind vector sensor system", ACS nano, Vol. 7, No. 10, pp. 9461-9468, (2013).
20. Zhang H., Yang Y., Su Y., Chen J., Adams K., Lee S., Hu C. and Wang, Z. L., "Triboelectric nanogenerator for harvesting vibration energy in full space and as self-powered acceleration sensor", Advanced Functional Materials, Vol. 24, No. 10, pp. 1401-1407, (2014) .
21. Cheng P., Guo H., Wen Z., Zhang C., Yin X., Li X., Liu D., Song W., Sun X., Wang J. and Wang Z. L., "Largely enhanced triboelectric nanogenerator for efficient harvesting of water wave energy by soft contacted structure", Nano Energy, Vol. 57, pp. 432-439, (2019).
22. Wang X., Niu S., Yin Y., Yi F., You Z. and Wang Z. L., "Triboelectric nanogenerator based on fully enclosed rolling spherical structure for harvesting low-frequency water wave energy", Advanced Energy Materials, Vol. 5, No. 24, 1501467, (2015).
23. Jin T., Sun Z., Li L., Zhang Q., Zhu M., Zhang Z., Yuan G., Chen T., Tian Y., Hou X. and Lee C., "Triboelectric nanogenerator sensors for soft robotics aiming at digital twin applications", Nature communications, Vol. 11, No .1, pp, 1-12, (2020).
24. Qin K., Chen C., Pu X., Tang Q., He W., Liu Y., Zeng Q., Liu G., Guo H. and Hu C., "Magnetic array assisted triboelectric nanogenerator sensor for real-time gesture interaction.", Nano-micro letters, Vol. 13, No. 1, .pp. 1-9, (2021).
25. Zhou Q., Pan J., Deng S., Xia F. and Kim T., "Triboelectric Nanogenerator-Based Sensor Systems for Chemical or Biological Detection", Advanced Materials, Vol. 33, No. 35, 2008276, (2021).
26. Dhakar L., Pitchappa P., Tay F. E. H. and Lee C., "An intelligent skin based self-powered finger motion sensor integrated with triboelectric nanogenerator", Nano Energy, Vol. 19, pp, 532-540, (2016).

27. Niu S., Wang S., Lin L., Liu Y., Zhou Y. S., Hu Y. and Wang Z. L., "Theoretical study of contact-mode triboelectric nanogenerators as an effective power source", Energy & Environmental Science, Vol. 6, No. 12, pp. 3576-3583, (2013).

28. Xu Y., Min G., Gadegaard N., Dahiya R. and Mulvihill D. M., "A unified contact force-dependent model for triboelectric nanogenerators accounting for surface roughness", Nano Energy, Vol. 76, 105067, (2020).

29. Min G., Xu Y., Cochran P., Gadegaard N., Mulvihill D. M. and Dahiya R., "Origin of the contact force-dependent response of triboelectric nanogenerators", Nano Energy, Vol. 83, 105829, (2021).

30. Al-Kabbany A. M. and Ali W. Y., "Effect of the Contact Force on Voltage Output of a Triboelectric Nanogenerator", Journal of the Egyptian Society of Tribology, Vol. 19, No. 3, pp. 1 - 9, (2022).