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Research Article

Application of Flexible Friction Nanogenerator and Sensor in Sports Safety Monitoring

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With the development of science and technology, nanotechnology gradually becomes the growing energy shortage of new energy technology, and gains more and more scientists' attention. Friction nanogenerator (TENG) is a nanogenerator with efficient energy conversion. Nanotextile (TEF-F) is a kind of friction material suitable for human skin, because nanotextiles have antibacterial function, radiation prevention, antistatic resistance, flame retardant, and other functions, and they can act on the outer layer of the skin and play a very good protective role. This article aims at studying a flexible friction nanogenerator and sensor as a safety monitoring equipment for sports. In this article, PTFE and nylon are proposed as friction nanomaterials of a flexible friction nanogenerator. A model of power generation by friction between insole and athlete is designed and tested. The experimental results show that the output voltage of PTFE friction nanomaterials with 50% water tightness can reach 200 V. Under the same conditions, compared with the output voltage of different textile fibers, the output voltage of nylon is up to 180 V. The output voltage of thin PTFE can reach 200 V, while that of nylon can reach 180 V. The output voltage of PTFE with medium thickness is 65 V, while that of nylon is 84 V. For thicker PTFE, the output voltage is only 58 V, while that of nylon is only 67 V. Therefore, for cotton, polyester, and nylon under the same conditions, the output voltage of nylon is significantly higher than that of different textile fibers. Moreover, for PTFE and nylon friction nanomaterials, the thinner their thickness, the higher their output voltage is.

1. Introduction

With the development of human beings for thousands of years or even tens of thousands of years, all walks of life in the world have developed rapidly, and energy has been continuously utilized and consumed by humans in recent decades or even hundreds of years. Therefore, the whole society has the problem of energy shortage, and there is also a serious energy crisis. And in recent decades, the large-scale use of fossil energy has not only brought great progress to the world economy and human society, but also caused a significant impact on the environment and climate around us; fossil energy can be used as a fuel for various means of transportation, which has brought a lot of convenience to human life, but the exploitation of fossil energy causes huge damage to the environment, and the greenhouse gases produced affect the climate. Since the reform and opening up in the last century, China's social economy has developed rapidly, and environmental problems have become increasingly prominent. The discharge of industrial wastewater, the increase in the PM2.5 content in air, the emergence of "smog," etc. not only restrict the development of the economy, but also seriously endanger human health. What's more, it will affect the health of future generations. Therefore, it is urgent to develop new energy sources to meet the needs of society.

Existing fossil energy is no longer inexhaustible as people once thought. Therefore, in order to deal with the existing energy crisis, it is necessary to develop other energy sources and find more and more sustainable energy sources for the human society. The specific sustainable energy source available is tidal power, wind power, hydroelectric power generation, and the friction nanopower generation studied in this article. Wearable fabric-based energy harvesters are increasingly important in use in portable consumer electronics as an eco-friendly energy source that can be independently self-powered through various activities. Wearable electronics include electronic watches, optical eyes, headphones, and electronic insoles. Using these wearable electronic devices combined with flexible friction nanogenerators to generate electricity will be a major energy development. Triboelectric generators can directly convert the energy in our living environment into electricity and are self-powered components of wearable devices. Wearable electronics urgently need flexible transparent triboelectric generators (FTTGs) with high-output power density, and functional polymers are outstandingly unique in the fabrication of smart devices such as sensors and actuators. Flexible friction nanogenerator can use the static electricity generated by friction collection to produce new green energy, with the characteristics of strong utilization and strong practicality. But it is rarely used to convert mechanical energy into electrical energy.

Renewable energy sources have developed rapidly, but these energy sources can only be used by industries or society, and it is not enough to rely on such resources alone. With the rapid development of science and technology in various fields, many remarkable research results have also been achieved. Therefore, experts use the existing research principles to convert some of the existing energy that appears around us into electrical energy through some common physical and chemical principles. It makes it more suitable for the needs of human life.

New forms of energy can collect energy from the surrounding environment and convert it into electricity for use. Among all kinds of energy, the mechanical energy generated by the human body is easy to be collected. Moreover, it can be used in a wide range, and is clean and environmentally friendly. And in the future, electronic products will become smaller and smaller, the quality will become lighter, and the use will be more convenient. This requires the energy supply products to have the advantages of small size, easy portability, and light weight under the premise of providing stable output power. Nanogenerators have the advantages. Therefore, the application of flexible triboelectric nanogenerators and sensors in this article is of great significance in sports safety monitoring.

The innovations of this article are as follows: (1) This article deeply studies a new energy source of F-TENG. (2) The new energy of F-TENG studied in this article will be applied to sports, which will be more friendly and promote people's exercise of sports. (3) This article tests and analyzes the designed new energy equipment to understand its time effect.

2. Related Work

With the continuous development of science and technology, nanotechnology has achieved good application in many fields. At present, many scholars have conducted in-depth research on TENG. Among them, Jeon found that layers with ZnO nanostructures were regularly formed on indium tin oxide-coated polyethylene naphthalate (PEN) substrates. The output voltage of the TENG-containing layers with ZnO nanostructures and operating in vertical contact separation mode is about 20 V. This shows a 2x power improvement compared to TENG without such layers [1]. Pingjian optimized the electrode structure by introducing graphene and indium tin oxide as transparent electrodes. He prepared FTTG with polyimide and polyethylene terephthalate as the friction layer and graphene as the top (bottom) electrode. Zhou also analyzed the effect of the electrode structure on the performance of FTTG and discussed the corresponding mechanism [2]. The multifunctional device designed by Guo can not only harvest tiny mechanical energy with high power density from ambient motion, but also detect dynamic forces with excellent sensitivity. This technology offers great application prospects in portable or wearable electronics, nanoelectromechanical devices, and self-powered sensors [3]. Choi addressed the output characteristics of a highly flexible Ni-Cu fabric-based triboelectric nanogenerator (F-TENG) employing a surface-imprinted polydimethylsiloxane (SE-PDMS) layer. Its method may provide a useful and simple route for developing self-powered, wearable, and smart electronics based on fabric substrates [4]. Kim showed that the choice of solvent used to dissolve polymers can significantly affect their performance in terms of energy harvesting. Kim confirmed by finite element method simulations that higher dipole moments lead to higher piezoelectric, pyroelectric, and triboelectric potential distributions. In short, his approach using high dipole moment solvents is very promising for high-output *P* (VDF-TrFE)-based wearable NG [5]. Deng developed a vibrator-based triboelectric nanogenerator (VTENG) by embedding a layer of silver nanowire percolating network into a dynamic disulfide bond-based vibrator elastomer. This self-healing and shape-adaptive VTENG by Deng has been shown to be useful in mechanical energy harvesters and self-powered tactile or pressure sensors with longer lifetime and excellent design flexibility. And the results show that incorporating organic materials into electronic devices can not only impart functional properties. It also provides a new approach for flexible device fabrication [6]. The research of the scholars provides certain theoretical help for the development of the F-TENG or sensor. However, these studies have not actually been used more due to factors such as high cost and complexity, so it is necessary to propose more improvement schemes. The research on the application of F-TENG and sensors in sports safety monitoring will be a real application combining theory and practice, which has important value and significance.

3. Safety Monitoring Model Based on F-TENG and FTNS

3.1. Flexible Triboelectric Nanogenerators. Triboelectricity is a well-known natural phenomenon that people live in, and the triboelectric effect is one of the few effects that people have known about for thousands of years. Although this phenomenon occurs every day in people's lives, there are still many debates about what the real physical mechanism is behind it. Electrostatic charges can affect the emission of radio signals, cause explosions, make MOS devices fail, and so on. MOS is a metal-oxide semiconductor field effect transistor, referred to as gold oxygen half-effect transistor [7], MOS devices use transistor devices, and are two symmetrical regions, even if the two ends are adjusted, it will not affect the performance of the device [8]. Therefore, triboelectricity has been regarded as a negative effect for a long time. Since then, the triboelectric effect has been widely used from its infancy stage to today, and then to energy harvesting and various self-driven mechanical sensors. With more and more in-depth and diverse research by researchers, the output performance of TENG is getting better and better, and it also plays an important role in the application scenarios [9, 10]. Figure 1 is a schematic diagram of the structure of the nanogenerator.

The technology of triboelectric nanogenerators provides a route to efficient energy conversion. The method can be applied in various practical fields, and its performance is sufficient to become an energy device to provide power. Triboelectric nanogenerator can be used to function since the power system of electrical response materials/devices, including artificial muscles, microactuator, memory device, electrostatic manipulator, air purification, electronic excitation, and ion generator [11]. The main applications of triboelectric nanogenerators can be divided into the following types: first, energy harvesters of vibrational energy to power self-charging systems; second, self-powered sensors, such as active sensors for medical, environmental monitoring, and security infrastructure; third, a basic network unit for harvesting low-frequency energy in the blue energy concept [12].

Vibration can be seen everywhere in our daily life. Vibration occurs in human movement, car driving, and even the fluctuation of water. Harvesting vibration energy as a long-term development and continuous improvement technology still has unlimited potential. However, the vibrations in the environment often have a wide frequency distribution and even change over time in many cases. At this point, triboelectric nanogenerators show unique advantages. It can work in a wide frequency range, and secondly, it can work effectively in the low-frequency range, and the common vibration frequencies in the environment are distributed in this range, such as human motion mechanical vibration, rotational motion energy, and wind energy and water wave energy [13].

With the continuous development of the Internet of Things, the core work unit, the sensor network, needs to carry more functions, and it needs to work independently without external power supply. As IoT sensors are widely distributed, their combination and use with traditional power sources will be a major challenge. Therefore, it is necessary to develop self-powered sensors that can utilize the energy in the environment to convert it into electrical energy. The amplitude, frequency, and period information contained in the voltage and current signals generated by the sensors are directly related to the mechanical input behavior of the device. In this part, various applications of self-powered sensors will be introduced, such as sensors for detecting ion concentration, human tactile sensors, and biomimetic membrane sensors and others [14].

Water waves are widely distributed around the world, and the energy contained in them is one of the richest. A hydroelectric power station is a typical method of utilizing the gravity of water. It can convert the energy contained in the water into electricity that can be used by people. Most hydroelectric power plants need to harvest energy from rivers, and tidal energy can also be harvested in some estuaries or coasts. As we all know, the energy of water waves in the ocean is extremely rich, and it will not stop no matter when or where. Very little space is required to collect this energy. And it is more secure. It is a green, sustainable, and environmentally friendly way to solve today's pressing energy problems [15, 16].

After the concept of self-triboelectric nanogenerators was proposed, there have been many related research studies on triboelectric nanogenerators in the world. In recent years, flexible textile materials have also gradually developed into the main material of triboelectric nanogenerators. It can be applied to the field of clothing, which provides great convenience for the energy supply of wearable devices in people's daily life. There are already attempts to combine this form of power generation with human clothing. Moreover, many textile materials can be used as the main friction material of the device, and the obtained triboelectric nanogenerator can be applied to the insole or connected with the sensor to provide electrical energy to some microdevices. Figure 2 shows several common flexible friction nanomaterials [17].

The current of free charge movement is actually a time-varying electric field, mainly from the slight movement of the charges in the atoms and the contribution of the dielectric polarization in the material. According to the displacement current variance in physics, it can be expressed as follows.

Gauss' law:

$$\nabla \cdot D = \rho_f. \tag{1}$$

Electromagnetism:

$$\nabla \cdot B = 0. \tag{2}$$

Faraday's law:

$$\nabla \cdot E = \frac{\partial B}{\partial t}. \tag{3}$$

Ampere's current law:

$$\nabla \cdot H = J_f + \frac{\partial D}{\partial t}. \tag{4}$$

Here, D is the displacement field, B is the magnetic field, E is the electric field, H is the magnetization field, ρ_f is the free charge density, J_f is the resource current density, and the displacement field is given as

$$D = \epsilon_o E + P. \tag{5}$$

Here, P is the polarization field and ϵ_o is the permittivity.

For displacement current, its expression is

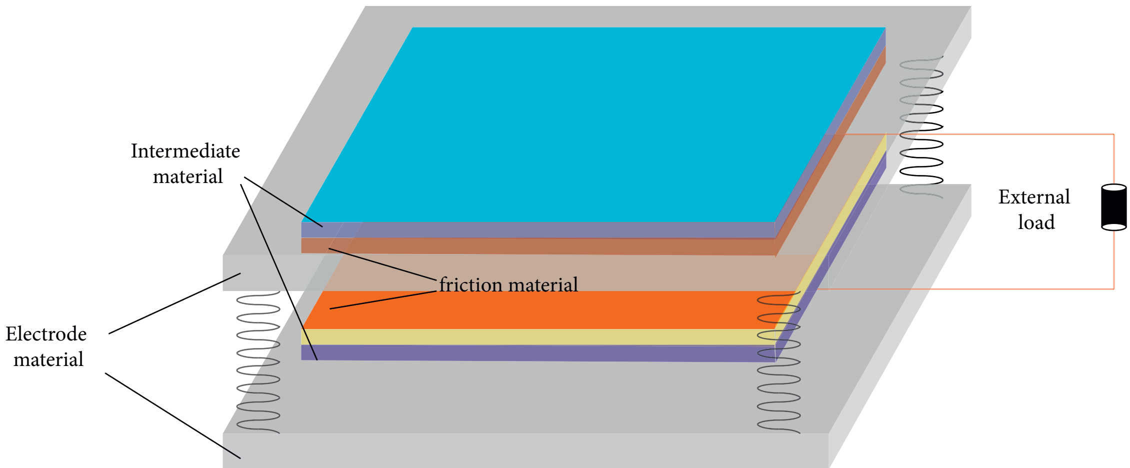

Figure 1: Schematic diagram of the nanogenerator.

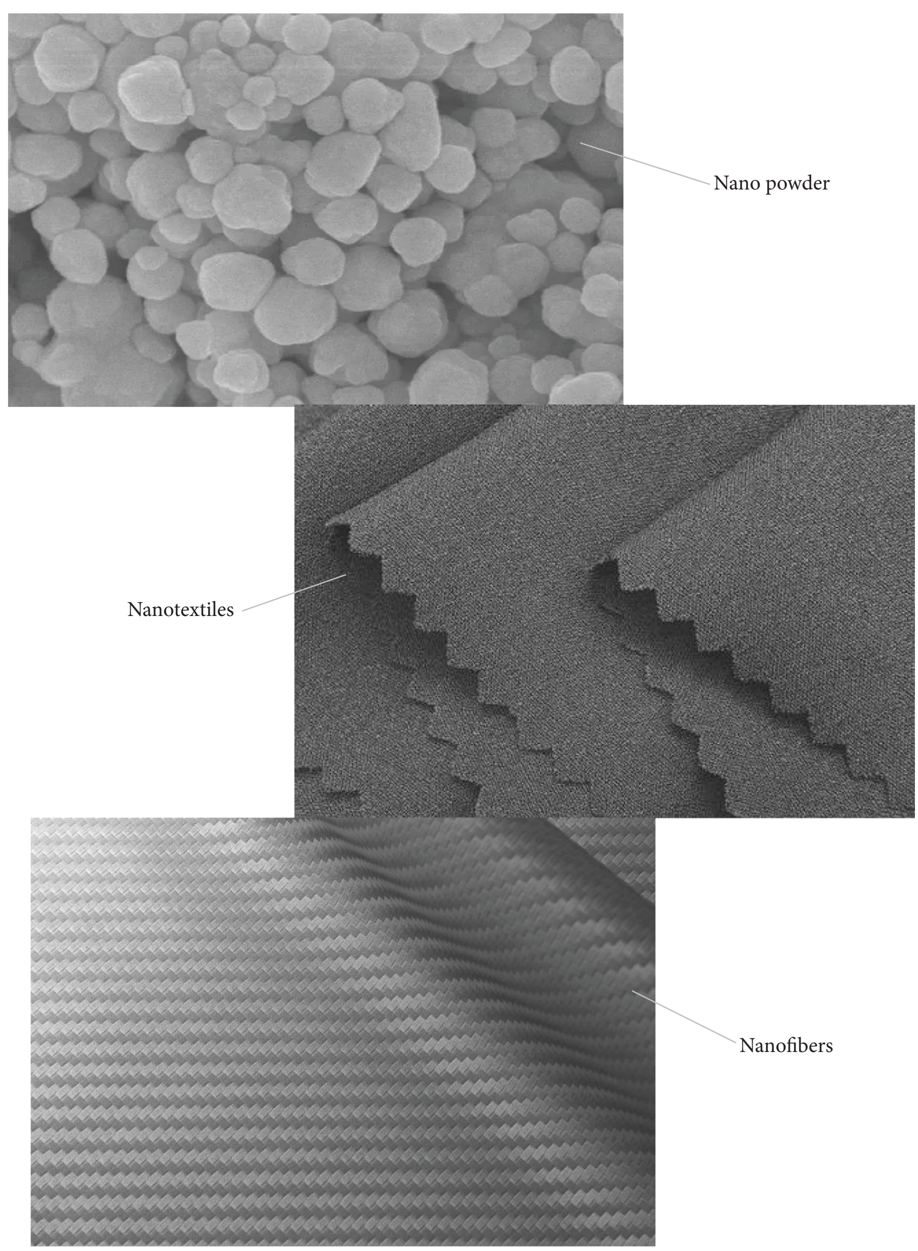

Figure 2: Flexible friction nanomaterials.

$$J_D = \frac{\partial D}{\partial t} = \epsilon_o \frac{\partial E}{\partial t} + \frac{\partial P}{\partial t}. \tag{6}$$

As time changes, the electrostatic field established by the triboelectric charge drives the current to flow through the external load, resulting in the accumulation of free electrons in the electrodes. As shown in Figure 3, the relative voltage drop between the two electrodes is

$$V = \sigma_1(z,t)\left[\frac{d_1}{\epsilon_1} + \frac{d_2}{\epsilon_2}\right] + \frac{z\left[\sigma_1(z,t) - \sigma_c\right]}{\epsilon_0}. \tag{7}$$

In short circuit, $V = 0$; at this time,

$$\sigma_1(z,t) = \frac{z\sigma_c}{d_1\epsilon_0/\epsilon_1 + d_2\epsilon_0/\epsilon_2 + z}. \tag{8}$$

Substituting the previous equation into formula (6), we get

$$J_D = \frac{\partial D_z}{\partial t} = \frac{\partial \sigma_1(z,t)}{\partial t}. \tag{9}$$

Affected by the external load, the current formula is

$$\mathrm{RA}\frac{\partial \sigma_1(z,t)}{\partial t} = \frac{z\sigma_c}{\epsilon_0} - \sigma_1(z,t)\left[\frac{d_1}{\epsilon_1} + \frac{d_2}{\epsilon_2} + \frac{z}{\epsilon_0}\right]. \tag{10}$$

Here, z is a function of time t.

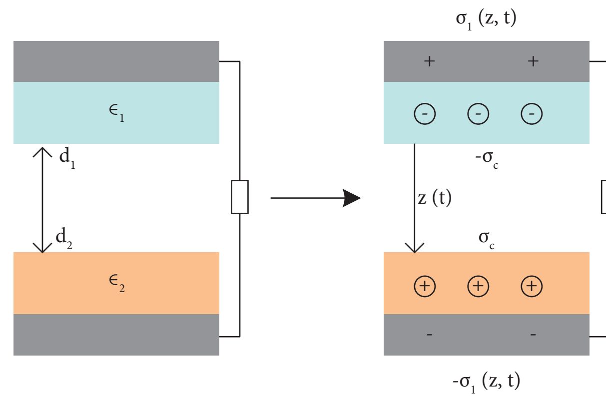

Figure 3: Working mechanism of the triboelectric nanogenerator with increasing number of contacts.

3.2. FTNS. Sensing and detection technology at the nanoscale has achieved rapid development in the past two decades. Due to the huge surface-to-volume ratio of nanoscale reactive devices, surface effects play a key role in the static and dynamic properties of nanoscale devices. In particular, for widely used nanosensors with thin films or substrate structures, changes in temperature can cause bending deformations and changes in natural vibration frequencies, thereby affecting the accuracy of sensing and detection [18].

The high-sensitivity nanosensors of the converter are mostly hetero-material stacked sensors of two materials. Among them, temperature, as the main influencing factor, can be changed by various conditions such as illumination, changes in room temperature, piezoelectric effect, and molecular adsorption and exotherm [19, 20]. In order to theoretically obtain the bending curvature and vibration frequency of the nanosensor under the influence, in the static analysis part, the deformation mechanism of the statically indeterminate sensor is studied in detail. It results in a theoretical prediction formula for the curvature of bending deformation. In the vibration analysis part, we only consider the effect of the temperature dependence of the material on the vibration frequency [21].

The bending curvature of the nanosensor is related to the type of adatom, the degree of temperature change, the material type of the film and the substrate on the sensor, and the change of the substrate thickness when the film thickness is fixed. It is independent of the length and width of the nanosensor. Nanosensors and nanomotion sensors change their natural vibrational frequencies when the surface is excited by atomic/molecular adsorption. By monitoring this frequency change, it can be used for sensing, as well as the identification and detection of atoms, molecules, and biological macromolecules (such as DNA and RNA) [22, 23].

In early experiments, people attributed the vibrational frequency shift of the micromotion sensor to the mass loading of adatoms or molecules. However, in subsequent studies, it was found that the surface stress during the adsorption process also affects the vibration frequency shift of the micromotion sensor. The research shows the temperature dependence of micromotion sensor materials, especially the temperature dependence of Young's modulus, that is, the "thermal excursion" effect. Among the effects of temperature change, it plays a major role in the influence of the vibration frequency of the micromotion sensor [24].

The analysis and discussion of the natural frequency of nanomotion sensors are developed on the basis of macroscale motion sensors. The vibration control formula of the double-layer heterogeneous material-laminated motion sensor after ignoring the effect of damping and shear stress is

$$-\frac{\partial^2 M}{\partial x^2} - F\frac{\partial^2 v}{\partial x^2} + (m + \Delta m)\frac{\partial^2 v}{\partial t^2} = 0. \tag{11}$$

Here, M is the moment, F is the axial force, v is the motion curvature, m is the motion mass, and t is the motion time.

If the axial force is ignored, the vibration control formula is simplified to

$$-\frac{\partial^2 M}{\partial x^2} + (m + \Delta m)\frac{\partial^2 v}{\partial t^2} = 0. \tag{12}$$

Then, the vibration frequency can be obtained as follows:

$$f_i = \frac{1}{2\pi}\left(\frac{\lambda_i}{L}\right)^2\sqrt{\frac{TD}{m + \Delta m}}. \tag{13}$$

Here, T is the time length, L is the length of the motion arm, and D is the equivalent coefficient.

And,

$$\cos\lambda_i \cos h\lambda_i + 1 = 0. \tag{14}$$

For the vibration frequency of the nanomotion sensor at different temperatures, the problem can be simplified to the discussion of the vibration frequency of the cantilever arch, and the derived vibration control formula is

$$\frac{\partial S}{R\partial \varphi}-\left(\rho_f A_f+\rho_s A_s\right)\frac{\partial^2 v}{\partial t^2}=0. \tag{15}$$

The resulting frequency formula is

$$2\cos\xi\frac{l}{R}\cos h\eta\frac{l}{R}+\left(\frac{\xi}{\eta}-\frac{\eta}{\xi}\right)\sin\frac{l}{R}\sin h\eta\frac{l}{R} -\frac{\left(1+\eta^2\right)^2}{\left(1+\eta^2\right)\left(1-\xi^2\right)}=0. \tag{16}$$

And $\eta\, and\, \xi$ satisfy

$$\eta=\sqrt{\frac{1}{2}\sqrt{1+4x^4}-1}, \quad \xi=\sqrt{\frac{1}{2}\sqrt{1+4x^4}+1}. \tag{17}$$

3.3. Sports Activity. At present, the Chinese government has increased the financial expenditure on public welfare sports year by year. However, due to the existence of objective reasons such as the weak foundation and late start of China's public sports undertakings, the related research on China's public sports is still relatively one-sided. There is a serious lack of safety benefits and service standards related to public sports, and public sports safety accidents and service quality problems occur frequently. The purpose of this study is to summarize research findings on the safety and services of public facilities around the world. Combined with the actual development status of China, this article conducts a survey on the safety and service of public sports. It initially constructs the framework of public sports management and service standards so as to provide technical support for the development of China's public welfare sports [25].

The core function of public sports is to provide the public with daily physical fitness services and realize people's demands for physical exercise facilities. The superordinate concept of public sports should be self-contained facilities. The implementation of sports refers to various venues, , buildings, fixed facilities, etc. used for sports competitions, training, teaching, and mass fitness activities. The basic function of sports is to provide users with buildings, venues, equipment, etc. that can be used for sports activities. Therefore, the primary goal of public sports as a subordinate concept of sports should be to meet the daily exercise needs of the masses. Figure 4 shows several common sports.

At present, countries around the world have researched and analyzed the main causes of personal sports injuries by consulting medical institutions' records of injured persons, and found that the primary safety hazard causing sports injury accidents comes from personal sports safety. The elderly and children often suffer from frequent injury accidents when exercising in public sports and fitness venues due to physical fitness constraints and contempt for sports safety.

Some surveys have shown that Chinese residents have a weak awareness of personal sports safety, and they have a serious fluke mentality. For the sake of temporary convenience, they give up the use of personal sports equipment. In the survey of personal fitness precautions, most respondents said they understood the precautions such as "avoid strenuous exercise after meals" and "choose suitable exercise according to their own conditions." However, there are still some people who ignore the safety and fitness precautions, resulting in frequent sports injuries. In the process of using public sports equipment, there are still some people who ignore the safety regulations for the use of equipment, resulting in sports equipment not being used correctly, and incidents of equipment injury are not uncommon.

4. Test of the Sports Safety Monitoring Model

4.1. Design of the Model. Triboelectric nanogenerator research has achieved some results. The selection of softer and less consumable materials has become the focus of research. The textile fiber material just meets the requirements for wearability. Therefore, based on the existing polymer triboelectric nanogenerators, this article explores the feasibility of various textile fiber materials in the preparation and application of triboelectric nanogenerators, and realizes the perfect combination of nanogenerators and textiles. Figure 5 shows the principle of the textile-like triboelectric nanogenerator chosen in this article.

In this article, based on the principle of triboelectric power generation and electrostatic induction, two kinds of fiber materials with strong gain and loss electron pairs were selected through experiments to prepare flexible triboelectric nanopower devices. It is finally combined with the insole. It converts the mechanical energy generated by the athlete into electrical energy and uses the electrical energy to monitor the sports safety of the athlete. The model designed in this article is shown in Figure 6.

The model is mainly composed of nanosocks made of nanotextile materials as nanogenerators. The athlete's movement is used to generate electricity, and the nanosensor collects the relevant data of the athlete's movement process. This article presents the data to the user through the mobile phone APP or electronic watch, so as to achieve the purpose of sports safety monitoring.

4.2. Simulation Experiment. The experimental instruments used in this article and their models are shown in Table 1.

When selecting the friction material, it should select two materials with stronger ability to obtain and lose electrons. During the contact friction process, each surface can accumulate more charges, and its external output electrical signal is enhanced. The power generation sequence of some friction materials is shown in Table 2.

In addition, the roughness of the surface of the friction material itself also has a great influence on the power generation efficiency. Therefore, appropriately changing the

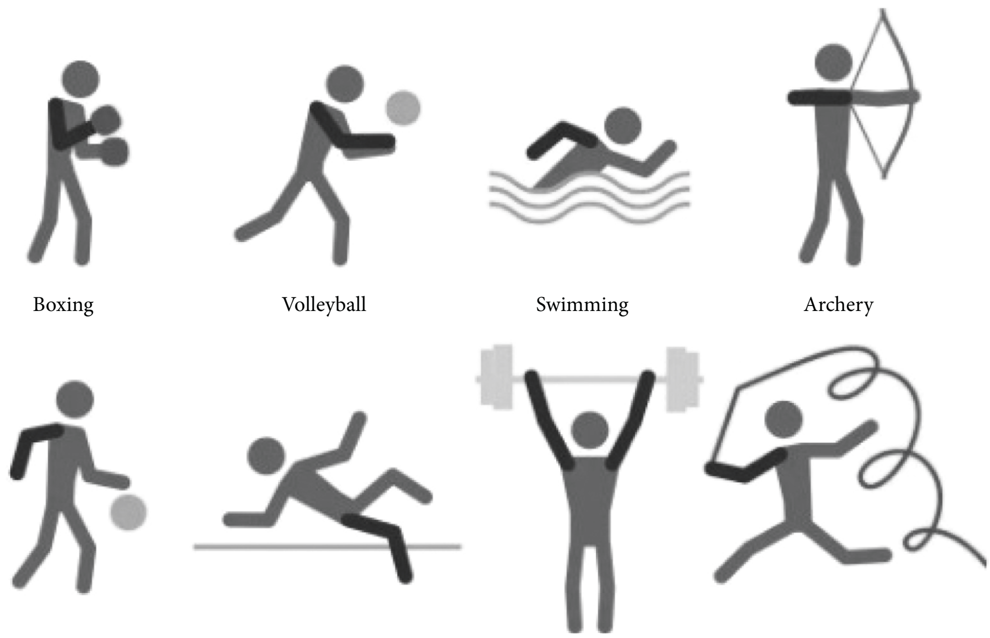

Figure 4: Common sports.

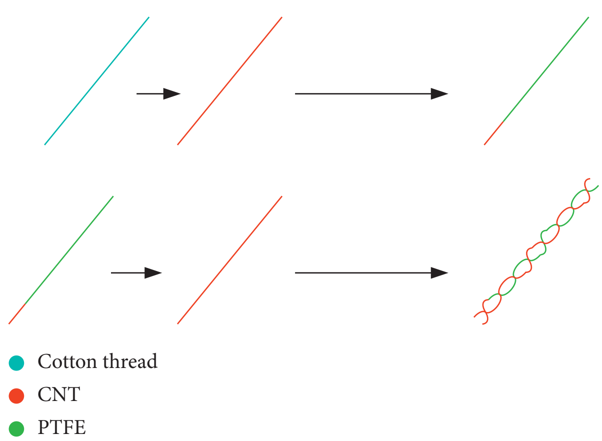

Figure 5: Principle of the textile-like triboelectric nanogenerator.

surface structure and morphology of the material and changing its roughness can also improve the power generation efficiency of the device. Therefore, two nanotextile materials, nylon and PTFE, are selected as the friction layer materials of the nanogenerator in this article. The two materials are shown in Figure 7.

In addition, the processes of nylon and PTFE nanotextile materials are shown in Tables 3 and 4.

4.3. Experimental Results. Finally, the output properties of the two friction nanotextile materials were obtained according to the simulation test, as shown in Figure 8.

It can be seen from Figure 8 that the output voltages of PTFE friction nanomaterials with different water tightness are quite different. Among them, the output voltage of 50% water tightness can reach 200 V. Compared with the output voltage of different textile fibers of cotton, polyester and nylon under the same conditions, the output voltage of nylon is significantly higher, reaching 180 V.

In addition, the output performance tests of different thicknesses of PTFE and nylon are carried out in this article, and the results are shown in Figure 9. The output voltage of thinner PTFE is 200 V, while that of nylon is 180 V, the output voltage of medium-thick PTFE is 65 V, while that of nylon is 84 V, and the output voltage of thicker PTFE is only 58 V, and that of nylon is only 67 V. The thinner the thickness of the two friction nanomaterials, the higher the output voltage.

5. Discussion

In this article, flexible textile materials are used as friction materials to prepare triboelectric nanopower generation devices. This article explores the influence of some properties of the material itself on the power generation efficiency. Affected by the research time and equipment, the subject needs further research in the following aspects:

(1) In this experiment, two different friction nanomaterials, PTFE and nylon, and their influence on the power generation performance of different thicknesses were studied. However, the weave structure of the selected fabrics is all plain weave, and the influence on the power generation efficiency can be explored by changing other different weave structures.

(2) In the process of weaving spacer fabric, only the influence of spacer yarn and fabric thickness on power generation efficiency was explored in this

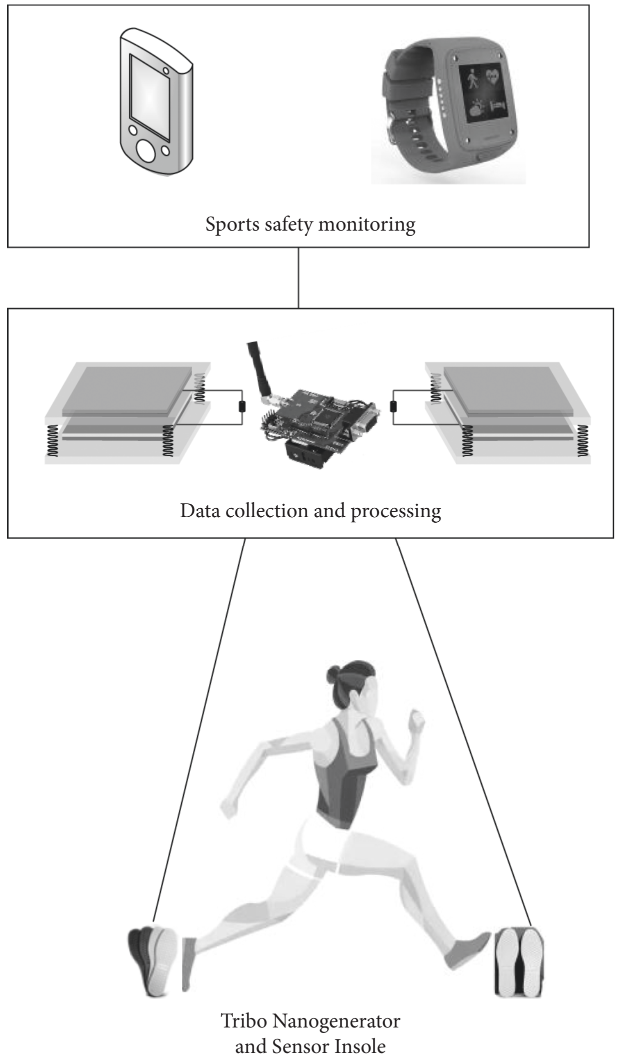

Figure 6: Motion safety monitoring model based on F-TENG and FTNS.

Table 1: Experimental instruments and their models.

Instrument	Model
Automatic Rapier loom	TNY101AB-20
Knitting computerized flat knitting machine	LXC-252SC
Resistance box	ZX21G
100 Catties testing machine	—
Oscilloscope	ZDS2022PLUS
Electrometer	KEITHLEY 6514

Table 2: Ranking of electricity-generating capacity of some tribo-nanomaterials.

Rank	Positive	Negative
1	Polyformaldehyde 1.3–1.4	Polybisphenol carbonate
2	Ethyl cellulose	Polychloroether
3	Polyamide 11	Polyvinylidine chloride (Saran)
4	Polyamide 6–6	Polystyrene
5	Melamine foam	Polyethylene
6	Wool, knitted	Polypropylene
7	Silk, woven	Polyimide (Kapton)
8	Aluminum	Polyvinyl chloride (PVC)
9	Paper	Polydimethylsiloxane (PDMS)
10	Cotton, woven	Polytetrafluoroethylene (Teflon)

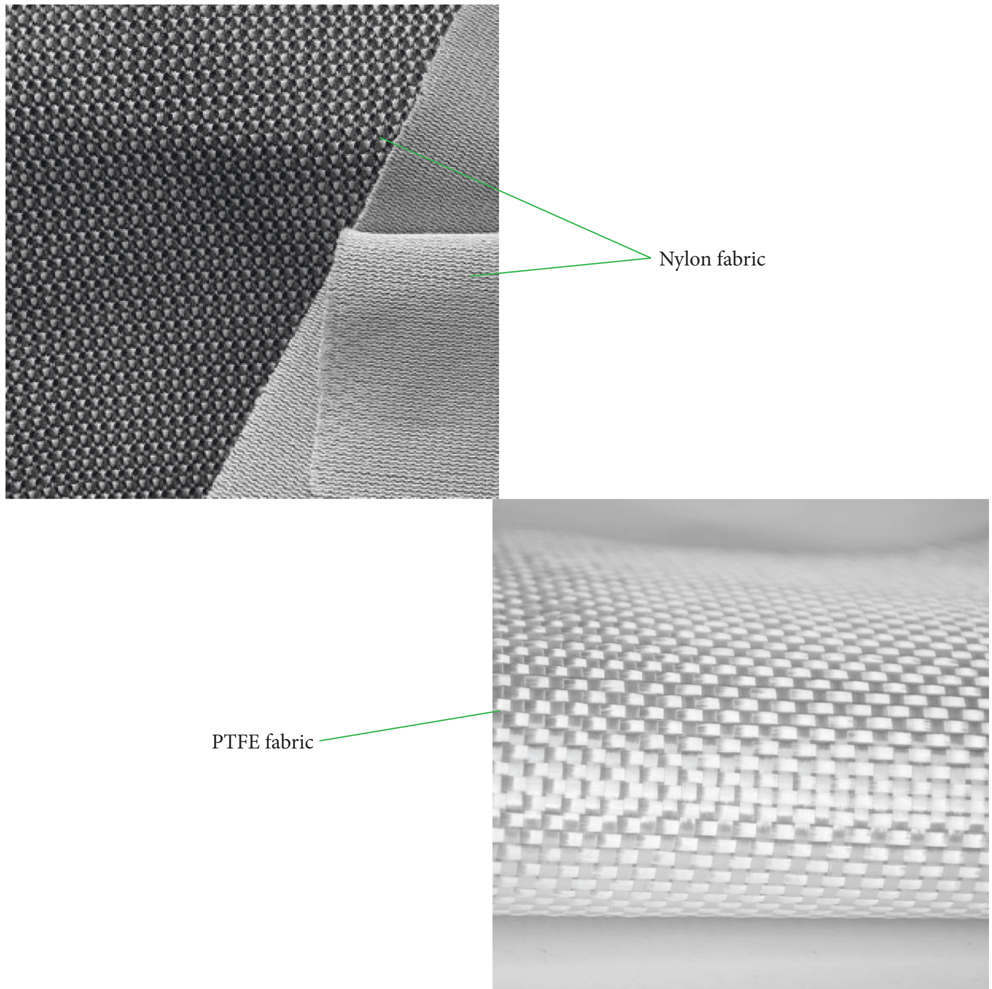

Figure 7: Nylon and PTFE nanomaterial fabrics.

Table 3: Nylon material technology of triboelectric nanogenerators.

Fineness (nylon)	Total warp root (root)	Reed width (cm)
150D/3	210	12.1
210D/3	178	12.5
280D/3	154	12.2

Table 4: PTFE material process of triboelectric nanogenerators.

Weft tightness (%)	Total warp root (root)	Reed width (cm)
10	138	11.7
30	138	11.7
50	138	11.7

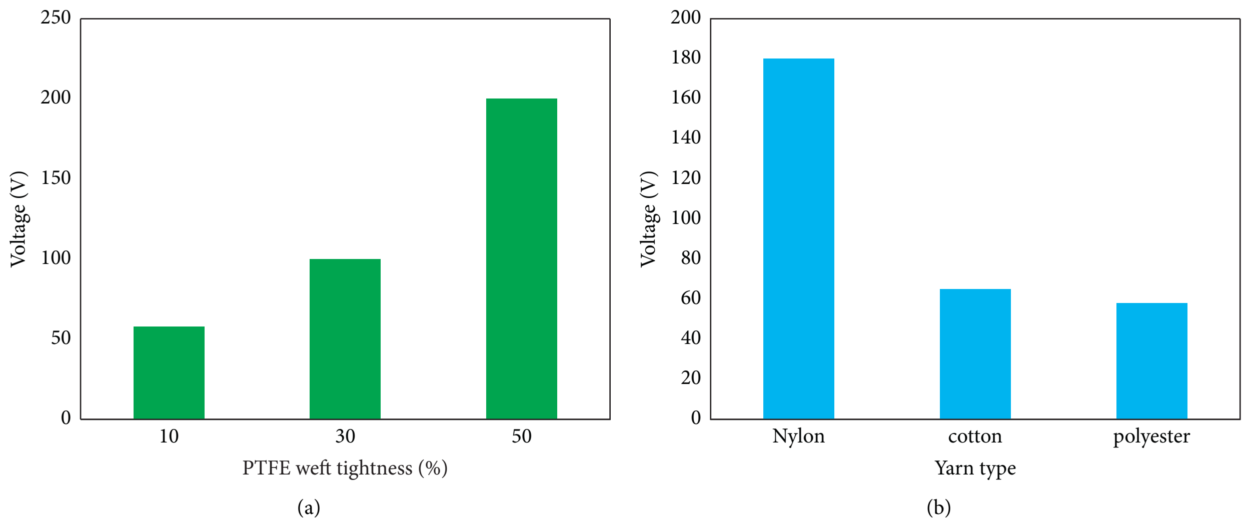

Figure 8: Output voltage comparison of tribo-nanomaterials. (a) Output properties of PTFE. (b) Comparison of output performance of nylon.

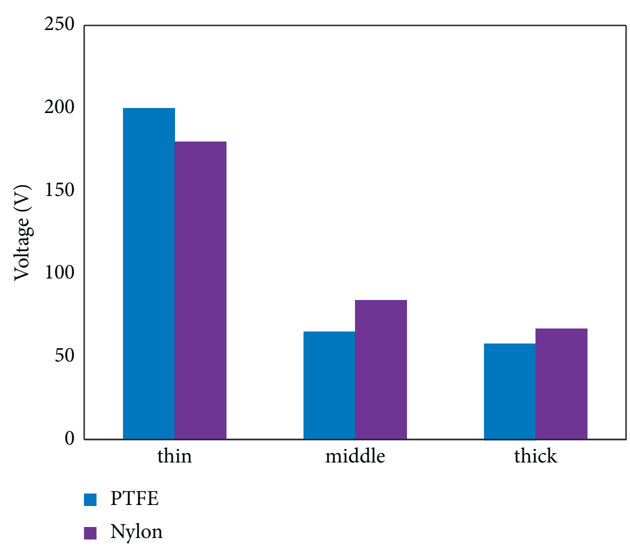

Figure 9: Comparison of output voltages of rubbed nanolayers with different thicknesses.

experiment. It can explore the influence of upper and lower layer yarn types on power generation performance.

(3) Due to the limitation of experimental materials, this article only explores the effects of two nanomaterials on the electrical output performance of triboelectric nanogenerators. It can further explore the effect of other nanomaterials on the output signal.

(4) In this article, the fabricated power generation device is only used in combination with the insole. It can also be used in conjunction with other electronic devices to provide electrical energy.

6. Conclusion

This article firstly gives an overview of the overall content of the full text in the abstract, and it then introduces the background of triboelectric nanogenerators in the introduction. It introduces the role of friction nanomaterials and summarizes the innovations of this article. In the related work part, some related research studies are exemplified in this article, so as to understand the current situation of the related content studied in this article. Then in the theoretical research part, this article firstly introduces the definition, characteristics, and classification and application fields of flexible triboelectric nanogenerators. This article secondly introduces the related content of nanomotion sensors and then introduces the related content of sports. It includes its types and characteristics. It finally proposes a motion safety monitoring model based on F-TENG and FTNS. In this article, the safety monitoring model is tested, and different friction nanomaterials are compared. The results show that the output voltage of PTFE friction nanomaterials with different water tightness is different. Compared with the output voltage of different textile fibers of cotton, polyester and nylon under the same conditions, the output voltage of nylon is significantly higher. And for the two friction nanomaterials, PTFE and nylon, the thinner the thickness, the higher the output voltage.

Data Availability

This article does not cover data research. No data were used to support this study.

Conflicts of Interest

The author declares no conflicts of interest.

Authors' Contributions

The author has read and approved the manuscript for submission.

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