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Design of a Rotating Drum for Electrospinning Setup with Adjustable Speed

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Abstract: This study is aimed to design a rotating collector drum to collect a large surface area of aligned polymeric fibers. There are some parameters that affect the degree of fibers alignment such as type of collector, speed of rotating drum, voltage, distance between syringe tip and collector, polymer concentration and feed rate. Collector drum having 80 mm diameter is selected to collect large surface area of fibers. Stainless steel is selected as the material of collector drum due to its resistance to corrosion in extreme acidic environments. In order to adjust the rotation speed of collector drum, AC motor is chosen as it uses electromagnetic induction to power the rotating device such as shaft. The safety, stability and suitability of rotating drum for large speed (>3000 rpm) were considered during the design. The rotating drum design in this project allows the production of nanofibers with controllable alignment.

Keywords: Rotating drum, Electrospinning, Aligned fibers

1. Introduction

The definition of nanofibers is the fibre which have at diameter in nanometer range [1]. Nanofibers can be used widely in biomedical, energy harvest and storage, electronics, healthcare and cosmetics, protective clothing, environmental protection, and filtration. Some studies have shown that cells cultured on aligned electrospun fibrous substrate, exhibit contact guidance for cell growth. In highly aligned nanofiber substrate, neurite outgrowth can be as much as 20% longer than that on random fibers [2]. There are many methods have been used to obtain nanofibers which are electrospinning drawing, phase separation, template synthesis and self-assembly [3]. Electrospinning method is the most popular method for electro-static production of polymer nanofibers [4]. Electrospinning normally used the application of a very high electric potential, syringe needle and collector.

Forming a high degree of nanofibers by electrospinning method is affected by two sets of parameters which are polymer processing parameters and solution parameters. Polymer solution conductivity, molecular weight, surface tension and solution viscosity can be categories in polymer

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solution parameters. While the processing parameters have electric potential, feed rate, temperature, orifice diameter, flow rate of polymer, and effect of collector.

2. Methodology

2.1 Solid cylindrical rotating drum

A solid cylindrical rotating drum was design to collect fibers as shown in Figure 1. The fibers are deposited align on the surface of collector drum with high rotational speed due to the acting of electric fields. The solid cylindrical rotating drum or known as collector drum is fixed by two stands in order to increase the stability of rotating drum during rotating.

Figure 1: A simple designed of solid cylindrical rotating drum

The function of collector drum is used to collect an alignment of nanofibers. The radius of collector drum is directly proportional to the curved surface area as follow the formula of $A_{curved\ surface} = 2\pi rh$. The diameter of collector drum is important as it will affect the surface area of nanofibers sample which is collected on the curved surface. The larger the surface area of nanofibers collected, the higher the flexibility of nanofibers. Moreover, it also help to reduce the time of experiment by having many specimen of nanofibers in one large pieces of nanofibers collected. Table 1 show the diameter of rotating collector drum and other parameter used by other researchers in electrospinning.

Table 1: Summary of the paramaters used for difference of researches on gelatin by using rotating drum as collector [5-7]

Type of Polymer	Diameter of Collector Drum, D (mm)	Length of Colletor Drum, h (mm)	Feed Rate (ml/hr)	Distance (cm)	Voltage (kV)	Speed of Rotating Drum Rotate (rpm)	Diameter of nanofiber
A 10 wt% gelatin from procine skin	50	300	0.18	10	12	4500	68.36±8.60 nm
2 ml of PCL solution	60	180	3	15	-	1000	1.78±1.07 µm
12 wt% of PCL	90	160	2	10.16	12	4500	1.34 6 0.44 µm

2.2 Material and Motor Selection

Stainless steel and aluminum were used as the material of collector drum in rotating drum [5]. These two material have the same properties such as conduct electricity and resist corrosion. But, stainless steel and aluminum have the different properties of weight, hardness, yield strength and others. The motor was selected based on the rotating speed required during electrospinning process. In electrospinning process, the rotating drum is required to rotate at the different speed which are 1000 rpm, 2000 rpm and 3000 rpm.

3. Results and Discussion

3.1 Rotating drum collector

There are total of 9 main components for electrospinning setup excluding screw. The electrospinning setup can divided into 3 parts. The first parts is rotating drum collector which functions as a collection of nanofibers. Next, the second part involves supporting of rotating drum and base which is required to increase the stabilization of rotating drum and adjust the distance between the rotating drum and the needle tip of syringe pump. Then the last part is motor system of rotating drum. The full 3D design of rotating drum setup is shown in Figure 2.

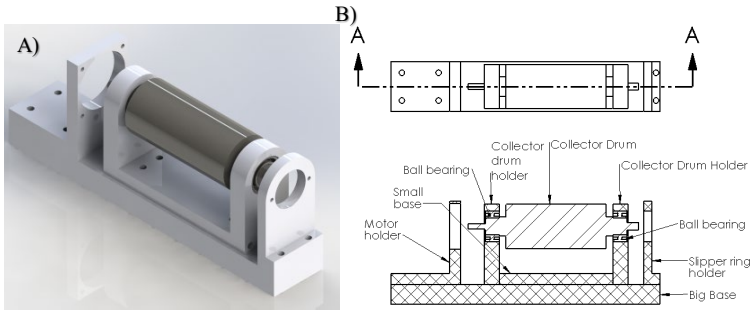

Figure 2: A) Full 3D design of rotating drum setup B) Partial view of rotating drum

3.2 Material selection

Stainless steel is more suitable than aluminum to be selected as the material of collector drum. Stainless steel is made up of iron, copper, nickel, manganese and chromium which is added as an agent to provide corrosion resistance. Next, non-porous properties help to increase its resistance to corrosion. While the surface of aluminum will turn white once it is oxidized especially in some extreme acidic or base environments, aluminum corrode rapidly with catastrophic results

3.3 Motor system

The collector drum is needed to rotate with an adjustable speed in between 1000rpm and 3000 rpm. Induction AC Motors can mean as asynchronous motors or rotating transformers. This type of AC Motor uses electromagnetic induction to power the rotating device which is usually the shaft. The size of this motor is suitable install in rotating drum setup.

3.4 Consideration in designing rotating drum

Rotating drum collector setup was chosen in this study in order to produce high degree of fibers alignment. During designing rotating drum, stability, safety and suitability required to be consider. When the time of revolution of the rotating drum coincide with a natural period of vibration of rotating drum setup, there occur the well-known phenomena of whirling and the corresponding speed of revolution is known as critical speed. In order to increase the rotating drum stability, the each side of collector drum had been assembled with collector drum holder. Next, Oldham coupling is used to connect the motor which driving shaft and the collector drum which driven shaft in mechanical power transmission assemblies. Oldham coupling design is help to resolve the misaligned in parallel between the motor shaft and collector drum shaft. When the misaligned problem had been solved, the stability of rotating drum setup is increased too.

Furthermore, the motor is fixed a motor holder. This will reduce the vibration of motor and increase the stability of motor. When the motor operate in stable motion, collector drum is also rotating

in stable motion. There have 2 base in this rotating drum setup, first one is the small base which is fixing the collector drum holder. The other one is big base which is fixing the motor holder and slipper ring holder. The function of base also helps to increase the stability of whole rotating drum setup.

For the safety of rotating drum, an output cable is requested to ensure there is an earth terminal on the slipper ring holder for a fault current to earth. So that, it can reduce this risk to human being and increase the safety. Oldham coupling can help to stop the transmission of energy in case of overload and minimize the risk of damage to rotating drum setup. Oldham coupling made up of 3 disk-shaped components, middle discs is made up of different plastics material and stay between the tongue and the grove design. This disc can insulate the electrical flow to motor. Moreover, the bases, collector drum holder, motor holder and slipper ring holder are made up of insulating material which is nylon. The electrical insulating properties of nylon help to prevent any unwanted flow of current to the earth coming from its supporting points. It also has excellent abrasion and wear resistance and low coefficient of friction. Next, the factor of safety, f_s calculated in is = 8.22 which means that it is safe to use 10mm as the minimum diameter at the end side of collector drum.

Lastly, the suitability of rotating drum setup is very important. The main of objective of this study is to produce align gelatin fibers by using electrospinning consisting of rotating drum by adjusting process parameters. Collector drum required to rotate at different speed such as 1000 rpm, 2000 rpm and 3000 rpm. A slipper ring is also used to connect the end shaft of collector drum. The slipper ring can allows the transmission of electrical signal and power from a stationary structure to a rotating structure. It can increase mechanical performance and reduce damage-prone wires dangling from movable joints.

3.5 Rotating speed

This design of rotating drum is aimed to produce aligned nanofiber. It Is because well-aligned or highly ordered nanofibers are important which is required in the biomedical field in order to imitate the fibres in the extracellular matrix (ECM) with the scaffold obtained. The rotating drum is the suitable collector to wind nanofibers in alignment and easy to be conduct as compared to other electrospinning method. The rotating drum was used to collect nanofibers and PCL was used as the material in the research [7]. The degree of nanofibers collected is affected by the rotating speed. The result in this research show that rotating drum rotate at 1500 rpm and 2000 rpm had obtained high degree of electrospun scaffolds.

4. Conclusion

A rotating drum with adjustable speed has been designed. Stability and suitability were considered during design. Consideration of safety is important to make sure the experiment of nanofibers collected is conducted in safety condition and reduce the risk to the human being. The material used for the bases, collector drum holder, motor holder and slipper ring holder is nylon which is insulating material. The reason of using nylon is to prevent any unwanted flow of current to the earth coming from its supporting points. The stability of rotating drum is considered for high rotating speed. Oldham coupling is used to improve the performance of rotating drum by connecting the motor which driving shaft and the collector drum which driven shaft in mechanical power transmission assemblies. It is also help to resolve the misaligned in parallel between the motor shaft and collector drum shaft. The rotating drum allows the production of aligned nanofibers by an electrospinning process. The adjustable rotating speed is expected to allow the fabrication of electrospun scaffolds with controllable fiber alignment.

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