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FLOWCONTROLOFPOLYMERUSINGSYRINGEPUMPAPPARATUSFOR ELECTROSPINNING NANOFIBER FABRICATION

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ABSTRACT

Electrospinningisananofabricationtechnique.Theprocessofelectrospinningiscommonlyusedtoproduce ultrafine fibers with nano meter-scale diameters. Through the use of a needle or spinneret, a polymer solution is electrostatically charged in this method.,formingafinejetthatisacceleratedtowards a collector. In this method, a syringepumpwith asteppermotor controller isusedtoprovide thecorrect flowrateofthe polymer solution tothe spinneret. Controlling the diameter and shape of the generated fibers depends heavily on the syringe pump. By adjustinganumberofvariables,includingtheflowvelocity,thevoltagebeingused,andtheseparationbetweenthe spinneret and the collector, the electrospinning process can be optimized to create fibers that possess specific properties. Thus improves the capability of generating high-quality nanofibers.

KEYWORDS: Syringe,SyringeNeedle,StepperMotor,StepperMotorDriver

INTRODUCTION

In the process of electrospinning, a syringe pump is utilizedtoregulatethespeedofdeliveringthepolymer solutiontothespinneret.Thespinneret,which canbeaneedleor anozzle,iswherethepolymersolutionisextruded intoanelectricfield to produce fibers. The syringe pump is crucial in maintainingastableflowrateofthepolymer solutionto ensureconsistentfiberdiameterandquality.Byadjustingthepumpingspeed, the syringe pump provides precision in controlling the flow rate, and it also helps prevent the polymer solution from becoming too diluted or drying out. To apply an electric potential to the spinneret, a tubing system typically links the syringepumptothe spinneret, with a high voltage power supplyoften integrated, which helps in the formation and stretching ofthe polymer fibers. The utilization of a syringe pump in electrospinning offers precise control of the polymer solution flow rate, which is necessary to attain the fiber properties.

LITERATURESURVEY

In [1] represents a syringe pump that is affordable and consumes low power, which has been designed to administer intravenous infusion Syringe pumps in hospitals with limited resources. The device is equipped with a constant-force spring to offer mechanical energy for depressing the syringe plunger.

Itcanoperateonrechargeablebatteriesforupto66hours,makingitidealforsettingswithunreliablepowergrids. Thedeviceiscompatiblewith5to60mLsyringesandhasaflowraterangeof3to60mL/hour.Itcostsaround $500toproduceoneAutoSyPdevice.Thedeviceunderwentlaboratoryandclinicalpilottestinganditslaboratory accuracy matched the planned flow rate within 4%.

In [2] the most widely utilized technique for creating nanofibers is suggested to be electrospinning. This tool has a high cost to buy onthe market.It offers a cheap substitute for the constructionof an electrospinningset up. The electrospinning setup's three fundamental components are as follows: The initial part of the system is a syringepumpthatforcesthefluid intothesyringeinordertoproduceaTaylorconethatishitbyhighvoltage.An electrical power source with a high voltage produces electrostatic force, which is the second component. The collectorbuildsupacollectionofnanofibergoods.Thesetup'sconstructioncostof$220.26islessthanthatofprior or shop-produced electrospinning setups. The article provides step-by-step directions on how to build the electrospinning setup and breaks down each of the three major components in detail.

In [3] the method applied by commercial syringe pumps to measure the flow rate by the diameter ofthe syringe.Thisvolume'sflowrateisthencomputedbydividingitby theamountoftime.Thisstudysuggestsusing aSensironLD20(SF04)flowsensorfordirectflowmonitoringtoimprovethesecurityofthedeliveryofhigh-risk drugs. It will be possible to assess the temperature of the medication that has been infusedand to spot air bubbles and occlusions as a result.

In [4] the Arduino nano ATmega328P, whichusesthe A4988 stepper driver to control aNEMA 17, isused to power the push-pull syringe pump (PPSP). An oled screen that has been C ++ programmed and a digital encoder can be used to change the Push-Pull Syringe Pump's configuration. A PCB was created and produced to make the device's assembly easier. A dampener designed specifically for this device and four non-return valves guarantee constant flow. flow rates and linearity are the final two.

In [5] The medical devices known as infusion pumps (IP) provide blood flow rate pressure is greater than theaveragebloodpressure.Theyarenecessaryfortherapiesthatdemandthepreciseandconsistentadministrationof food or medication. Due to their classification as Class III (high-risk) devices, they require regular maintenance in order to function properly and to protect the operator and patient. A lack of maintenance on the apparatus may lead toavolumethatisunknownandtheadministrationofsubstanceswithinaccuracy.Thismonitoring,whichalsooffers an indication of the efficacy of the finished product, ensures the quality of the desired infusion outcome.

In [6] the capacity to create electrospun polymer nanofibersthat are the rightdiameter and shape. By adjusting thepolymersolution'sconcentration,electricalconductivity,andsurfacetension,thesizeandshapeofthenanofibers maybechanged..Theelectrospinningprocessneedstobebettermanagedinordertomanufacturepolymernanofibers in an efficient manner. With typical dimensions ranging from 100 to 400 nm, this technology made it possible to successfullyproducepolyacrylonitrileandpolyvinylidenefluoridenanofibers.Real-timeelectricalandoptical observationswereusedtomonitortheelectrospinningprocessandchangeexperimentalvariables.

In[7]A control system for a syringe pump can optimize the volume and flow rate of the solution. The syringe pump'sstepper motor drivesthe syringes, whilean ArduinoUno boardmanages the pump'soperation. For input,a matrix of keypadsand a four-digit seven-segment display are utilized. The system makesuse of an injection pump withspeedadjustmenttoadjusttheflowratetotheappropriatelevel.Theflowrateandvolumemaybeadjustedby the stepper motor. The syringe pump can handle flows that vary from 0.10 to 12.00 ml/hour. In addition, the technology can be used to regulate drug fluid flow rate and volume in clinical settings.

The [8] SEM was used to qualitatively investigate the electro spinnability of different aqueous solution concentrationsandPVAtoGlyweightratios.Whereelectrospunforeachconcentration,resultinginfiberswithan average diameter ranging from 232 nm to 591 nm. The effect of solution c was also investigated.

In[9]Infusionpumpsaremedicalequipmentusedinclinicalsettingstomanagetheadministrationoffluidslike nutrients into patients' bodies. Infusion pumps are machines used often in hospitals, nursing homes, and other healthcareinstitutionstoprovideessentialfluids,includinghigh-riskdrugs.Theycomeinmanydifferentforms,some of which are made expressly for stationary usage by a patient's bedside, such as large volume, patient-controlled analgesia, and insulin pumps. Pump malfunctions may affectthe patients' safety. It produces a compactsyringe pumpsmallerthantheconventionalones,weighing less and can be lifted with one hand.

In [10]to improve drug safety, this article advocates using technology to administer medications. Infusion devicesknownas"smartpumps,"whichhavedrugconcentrations,doses,andothercharacteristicspreprogrammed, are crucial to the digital safety revolution. It is impressive how well they can cross-check each other and guard againstunintentionaldoseorconcentrationvariations.Itwilltakealotofworktoimplementthistechnology,thus careful, collaborative, and coordinated efforts are required..

In [11], Using only four processes and no pumps, a three-layered device is presented that might be used to producecore layers that arealigned in a hydrogel sheet. A possible option is a sensor chip in the form of a sheet for sensor-cell arrays. The usage of microfluidic devices with syringe pump systems led to a reduction in sample volume and an increase in setup time in order to produce heterogeneous cell pattern hydrogel sheets. A small amount of sample and a single hand pipette can be used with the designed equipment to produce hydrogel sheets.

EXISTINGTECHNOLOGY

A.PUSH-PULLSYRINGEPUMP[4]

ThePush-PullSyringePump(PPSP)isdrivenbyanArduinosmallATmega328PunderthecontrolofaNEMA17 thatismicro-steppedbyanA4988steppercontroller.Push-PullSyringePumpsettingscanbealteredusingadigital encoder (Manual Input) and an oled screen made in C++. A PCB was developed to facilitate the creation of the device. Continuous flow is guaranteed by four non-return valves and a dampener that is sized and optimized for usage with this apparatus. Tests were done at the conclusion to assess the flow rates and linearity of the flow.

WORKING

Thesketchisdividedinto5tabs;themainoneisnamedPPSPSoftware(supplementarymaterials)andruns the main loop; the other 4 are additional functions, one for the auto home function at startup, one for screen management,and twoothersfor themanagementof the digital encoder. The NEMA17 isdrivenin14 step(micro stepping),thepowersupplyisconnectedtotheNEMA17,andthesoftwarewaswrittenandimplementedusingthe Arduino IDE equipped with the U8g2lib library.

HARDWARESETUP

The slider location is known.At this point, The movement of the slider can be managed by two for loops. To move the slider from right to left, The driver of the NEMA motor receives explicit digital HIGH and LOW signalsthat areswitched witha specifieddelayfromaforloop.The sliderissimilarly movedfromleft to rightby theotherforloop.TheamountoftimebetweenHIGHandLOWsignalsisdeterminedbytheflowratethattheuser sets; this time is expressed in milliseconds for low flow rates and microseconds for high flow rates.

Thesoftware'sothercomponentwascreatedtomakeitsimpleforthepumpandhumanactivitytointeract. The code required to display the flow rate on screen as well as an instruction to the pump is specifically found in the file "Message_to_Oled.ino."

The pump will turn on when the power plug is plugged in, and each time it does, the system will run an Auto Home to reassess the location and distances.

Figure3.1PictorialRepresentationofPUSH-PULLSYRINGEPUMP[4]diagram

PROPOSEDSYSTEM

A.PRELUDE

Choosing the proper syringe and needle, adding the polymer solution, and attaching the syringe to the syringe pumpareallstepsintheprocedure.Afterthat,thesyringepumpisadjustedtoguaranteeapredictableandcontrolled flow rate. For the particular experiment, operating factors like voltage, the distance between the needle and the collector, and flow rate are optimized. To produce uniform nanofibers during the electrospinning process, feedback onthesyringepump'sperformancemustbecloselymonitored.Topreservethesyringepump'slongevityandaccuracy insubsequentstudies,itshouldbeproperlycleanedandmaintainedaftereachexperiment.Thesestepscanbeusedby scientists to use the syringe pump configuration in electrospinning to create superior nanofibers.

B.DESIGN

The functionality of the syringe pump relies on a system driven by a piston, which allows for the configuration tooperateataconstantorpulsatileflowrate.Thesystemappliespressuretothepolymersolutionthroughtheuseof apiston in thesyringe, whichforcesthesolutionthroughthetubing tothespinneret.By adjusting thepump'sspeed via a programmed control unit, it is possible to precisely regulate the flow rate of the pump, which also makes it possible to precisely manage the volumetric flow rate and the solution delivery rate. The syringe pump's ability to regulateboth itsflowrateandelectricpotentialallowsfor consistentand uniformproduction ofnanofibersinterms of size, shape, and morphology. In conclusion, the syringe pump is an indispensable component of the electrospinning process, which enables consistent and stable production of high-quality nanofibers with uniform diameters.

AnArduinomicrocontroller,asteppermotor,asyringepump,andamotordrivermakeupthedevice.Thestepper motor,whichismanagedbytheengagementofthedrivingscrew,drivesthepistonofthesyringepump.Theamount of fluid dispersed by the system is directly proportional to the number of step rotations, and the direction and speed of the step rotation determine the pumping speed. Effective motor control is made possible by the motor driver.

The Arduino microcontroller controls the motor and determines how quickly polymer solution is delivered. By providing electrical signals to the motor driver, which initiates the direction and steps, the programmed running on the Arduino controls the motor.

The implementation of the method, which makes use of a, allows for the precise control of the pump flow. The stepper motor interfaced with the Arduino microcontroller plays a crucial role in maintaining the syringe pump's operationtoensureconsistentflowratesthatenableuniformnanofiberdiameterandquality.Thepreciseandaccurate flow rates due to volumetric control enable the production of nanofibers with uniform characteristics.

Using a stepper motor and an Arduino microcontroller in the electrospinning process provides a cost-effective, precise, and accurate syringe pump system. This hardware allows for a controlled and precise flow rate of the polymer solution, which ultimately enables consistent and uniform nanofiber production.

C.METHODOLOGY

SetupOfEquipment

Asyringepump,ahigh-voltagepowersource,aspinneret(needleorcapillary),acollectionsubstrate,andagrounded plate are common components of an electrospinning system. Make sure that every part is securely fastened and connected.

MakingofMaterials

Preparetheelectrospunpolymersuspensionorsolution.Inordertodothis,thepolymermustbedissolvedordispersed in an appropriate solvent or solvent mixture. Adjust the concentration of the polymer solution based on the desired fiber properties.

SyringeFilling

Fill a syringe with the prepared polymer solution. Ensure that there are no air bubbles trapped inside the syringe, as theycandisrupttheflowandaffecttheelectrospinningprocess.Theinfusionfillingaremadeupoforganicpolymers like PVA Polyvinyl Alcohol

ConfigurationoftheSyringe Pump

Thesyringepumpshouldbesetup inaccordancewiththemanufacturer'sinstructions.Inordertodothis,thecontrol panel of the syringe pump must normally be programmed with the desired flow rate, volume, and other parameters. Make sure the syringe pump is calibrated correctly and prepared for use.

ElectrospinningParameters

Electrospinning Conditions Establish the electrospinning parameters, such as the applied voltage, the separation betweenthespinneretandthesubstrateforthecollection,andtheambienttemperatureandhumidity.Dependingon the particular polymer and desired fiber qualities, these factors might need to be optimized. The physical environmental conditions outside and the characteristics of the polymer substrate utilized in the process are what determine the parameters.

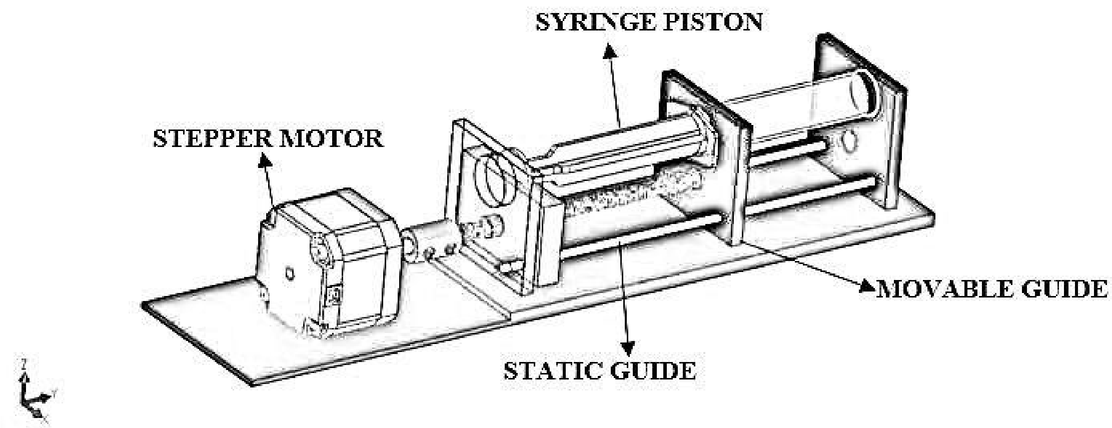

Figure4.1PictorialRepresentationofProposedhardwaresystemdesigndiagram

Figure 4.1 shows a single Pump is designed in the solid works software to run independently of the rack's other pumps. Software is used to execute simultaneous pump movements.

D.WORKING

A syringe pump equipped with a stepper motor and an ArduinoUno board can further enhance the efficiency, precision, and adaptability of the electrospinning process.

The stepper motor controls the rotating plunger that pushes the polymer solution through the needleand outof the syringe. Thestepper motorallowsforincredibly preciseandfine-grained controloftheplunger'smovement,while the ArduinoUno board'spulsesregulate itsspin. To control the steppermotor'sspeed andpulsewidth modulation, theArduinoUnoboardcanbeprogrammed.Thiswillcontrolhowquicklythepolymersolutionflows.Thesyringe pump with stepper motor and Arduino Uno board has the capacity to deliver a steady and accurate feed rate of the polymer solution to the needle tip in order to guarantee a consistent fiber diameter.

TheuseofanArduinoUnoboardfurtherenhancesthecapabilitiesofthesyringepumpbyprovidingacontrollerfor theentire electrospinning system. The Arduino Uno board can control various parameters of the electrospinning process, including the applied voltage, distance between needle and collector, feeding rate, and other operational parameters.The appliedvoltage causesthefibersto stretchand elongateastheytravelfromtheneedletothecollector, resultingintheformationofthinfibers.Syringeswithcapacitiesof5ml,10ml,and20mlcanbefastenedtothepump thanks to the design.

For electrospinning,thepolymer solution isputintothe syringe, and the steppermotor and ArduinoUnoboardof the syringe pump regulate the speed at which the solution is delivered to the needle. By applying a high voltage whentheneedleispositionedataspecificdistancefromthecollectingplate,thepolymersolutioniselectrospun ontothecollector.Varyingtheparametersallowsforprecisecontroloffiberdiameter,alignment,andmorphology. Asyringe pump equipped with a stepper motor and an Arduino Uno board can further enhance the efficiency, precision, and adaptability of the electrospinning process.

Thestepper motorcontrolsthe movingplunger thatpresses thepolymer solution from the syringe and through the needle. Because of the stepper motor, which rotates the plunger using pulses sent by the Arduino Uno board, movement can be done with fine control and extraordinary precision. To control the flow rate, the Arduino Uno boardcanbeprogrammedtocontrolthestepangleofthesteppermotor.Asaresult,aconsistentandaccuratefeed rateofthepolymersolutiontotheneedletipmaybeprovidedbythesyringepumpwithsteppermotorandArduino Uno board, resulting in a fiber with a consistent diameter.

TheuseofanArduinoUnoboardfurtherenhancesthecapabilitiesofthesyringepumpbyprovidingacontrollerfor theentire electrospinning system. The Arduino Uno board can control various parameters of the electrospinning process,including the applied voltage, distance between needle andcollector,feedingrate,andotheroperational parameters. The appliedvoltagecausesthefibersto stretchand elongateastheytravelfromtheneedletothecollector, resulting in the formationof thin fibers.

Thepolymersolutionisinjectedintothesyringebeforethesteppermotor-drivensyringepumpisusedtoelectrospun thematerialandArduinoUnoboardcontrolsthefeedrateofthesolutiontotheneedle.Byprovidingahighvoltage whentheneedleispositionedataspecificdistancefromthecollectingplate,thepolymersolutioniselectrospunonto the collector. Varying the parameters allows for precisecontroloffiberdiameter, alignment, and morphology.

E.RESULT

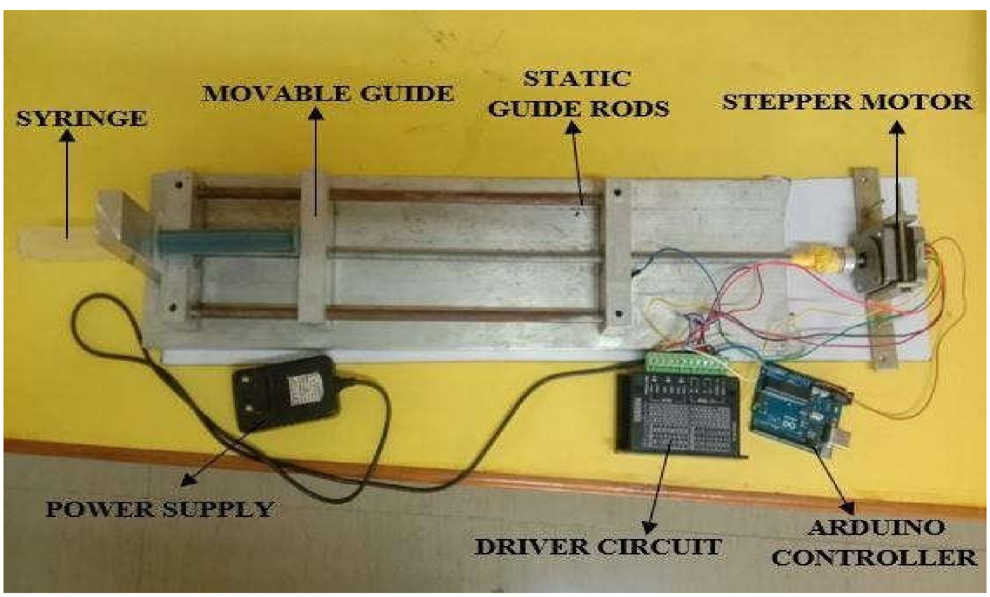

Figure4.2PictorialRepresentationofPrototypemodeloftheHardwareSystemdesign

TheprototypemodelisshowninFig.4.2isthehardwaresetup.Thecomponentsareconnected.Thesehardware componentsimpactsthesyringepump'soutput,includingthefollowing:

Motorspeedandtorque

The stepper motor in the syringe pump is responsible for driving the pump'splunger, and itsspeed and torque determinethe fluid flow rate and the accuracy of the delivered volume.

Drivemechanism

The drive mechanism of the syringe pump controls the position of the plunger, and its accuracy and precision impact the volume of the fluid delivered.

Syringesize

Thesyringesizeimpactsthevolumeandflowrateofthedeliveredfluid.Thehardwaresetupshouldbe compatible withthe syringe size selected for the experiment.

Syringeholder

Thesyringeholderholdsthesyringeinplace,ensuringthattheplungermovespreciselytocontrolthefluidflow rate.

Powersupply

Thehardwaresetuprequirespowertoprovidecontrolthesyringepump'soperation.Theappropriatepowersupply will depend on the specific syringe pump model and manufacturer.

CONCLUSION

1. Weconcludethattheuseofsyringepumpinelectrospinninghasproventobehighlyeffectiveincontrollingthe flow rate ofpolymer solutions.

2. It offers accurate control and precision overthe electrospinning process, ensuring the production of uniformand consistent nanofibers. The use of syringe pump in electrospinning, it can be concluded that it is a highly effective technique for controlling the flow rate of polymer solutions to produce uniform and consistent nanofibers.

3. Thesyringepumpoffersaccuratecontrolandprecisionduringtheelectrospinningprocess, making itan essential toolinpolymernanofiberfabrication.Thesyringepumphasproventobeanessentialtoolforelectrospinning,andits future scope holds a lot of potentialfor innovation and progress in the field.

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