EXPERIMENTAL INVESTIGATION OF POLYURETHANE ELECTROSPUN NANOFIBERS MAT----RELATIONSHIP BETWEEN MECHANICAL PROPERTY AND THICKNESS

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***Abstract*-- Electrospinning is a method to produce polymer fibers from solution with diameters ranging from 100 to 500 nm. Pure Polyurethane was electrospun from solution to produce an isotropic fiber mat. The mechanical behavior such as stress-strain curve and maximum load during fracture of the mat was characterized by uniaxial tensile tests. Scanning electron microscopy was used to characterize the electrospun material. Finite Element Analysis method is utilized to simulate stress distribution. The experimental result shows that the maximum load increases when the thickness increases.**

Keyword: Electrospinning; nanofibers; tensile testing; mechanical properties; polyurethane; FEA analysis

1. INTRODUCTION

Electrospinning was invented in 1934 by Formhals [1], which is currently the only technique that allows fabrication of nanoscale continuous fibers. Since the fiber diameter is range from several micrometers to a few nanometers [2], this technique becomes a novel and economical method to fabricate nanostructure, which brings a broad range of applications. These include membrane for polymer battery, tissue engineering scaffolds, Gas sensors, thermal Interface materials. Also, electrospun nanofibers have extremely long length and high specific surface areas, thus, have shown strong potential application in biomedical fields, such as in vascular, neural, and tendinous tissue engineering [3]. For all these application and the promising future of Electrospinning application, increasing number of research is undertaken for 20 years since 1990s.

Currently, there is a limited number work on the mechanical properties of electrospun nanofibers mat. [4, 5]. This study examines the relationship between mechanical properties and the thickness of electrospun nanofibers mat with tensile testing. The experiment result is analyzed with FEM method. Further recommendation is presented in the paper.

2. EXPERIMENTAL

2.1 Materials

Thermoplastic Polyurethane (PU) elastomer were dissolved in a mixture of THF and DMF (60/40, v/v) at room temperature to a fixed weight concentration of 18%. After Electrospinning, five samples of fiber mat produced were dried to remove the residual solvent.

2.2 Electrospinning Process

Each PU solution prepared was poured in a 20-ml syringe attached to a capillary tip of about 1mm diameter. An alligator style clip was used to charge the syringe tip, and solution with flow rate of 0.050ml/min was electrospun onto a grounded collector wrapped with Aluminum foil. The distance between the capillary tip and the grounded collector is 20cm. The electric field was set to 18KV generated by a high-voltage power supply.

2.3 Mechanical Behavior

As Fig 1 shows, tensile testing with grip system was carried out using an Instron micro-functional mechanical tester.

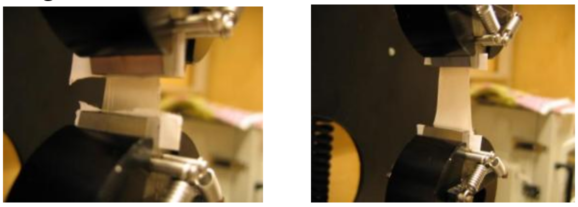

Fig 1, the electrospun nanofibers has elastic property

3, RESULTS AND DISCUSSION

3.1 Mechanical Properties of electrospun PU

For 5 samples with different thickness, as shown in Figure 2, maximum stress strain, load are summarized in Table 1. In the test sample, except the thickness, the dimension of length and width remains the same.

Thickness (micron)	Max stress MPa	Max strain	Maximum load L (N)
2.89	16.55405	1.726204	0.161761
3.6	12.19649	1.21584	0.225976
8.6	11.28568	1.69146	0.35766
37	1.67193	1.580181	0.25479
43	2.83089	1.567605	0.50771

Table 1: experiment result summary

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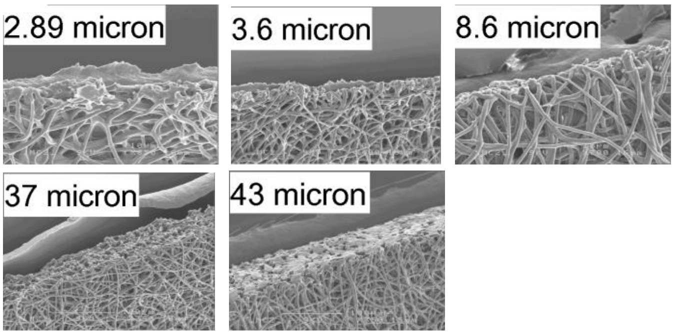

Fig 2, SEM pictures of samples with 5 different thicknesses

Fig 3,4 shows the relationship between mechanical properties of electrospun nanofibers mat and the thicknesses. Although the thickness of the mat increases, it does not affect the maximum strain. The reason could be due to the fact that mat is fabricated with the same material and same procedure. It is possible to manufacture the mat with lower volume of solution, but can still gain sample with similar elongation property. However, the maximum load is in direct proportion to the increase of mat's thickness. The phenomena that, at the break point, the maximum stress is in inverse proportion to the thickness augment, is caused by the fact that the scale of sample's cross-section area aggrandizes in a relatively larger extent to that of maximum load.

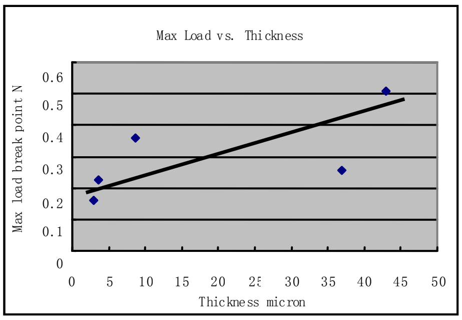

Fig 3, Relation between thickness and Maximum Load at breakpoint

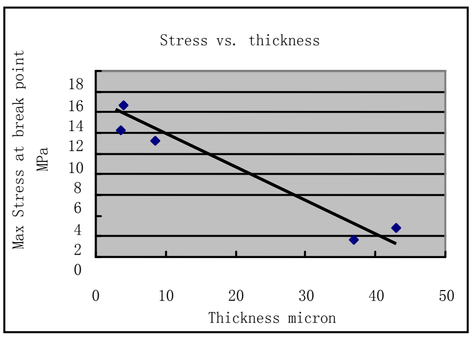

Fig 4, Relation between thickness and Maximum stress at breakpoint

3.2 Finite Element Analysis Simulation of Tensile Testing

By the FEA method, the fiber is modeled and simulated with software MSC.Patran/Marc according to the tensile test. In software, the material constitutive model of fiber is described as elastic, plastic and failure. For the simulation involves non-linear of material, the simulation is conducted by implicit arithmetic. While modeling, the dimensions of fiber section are 19 mm × 5 mm, and the thickness is 0.0086 mm. The up edge of section is exerted a 0.357 N magnitude tensile force, and the down edge of section is fixed, which is similar to the test. Finishing the same conditions setting, the simulation is processed. The results are presented as figure 6 shows.

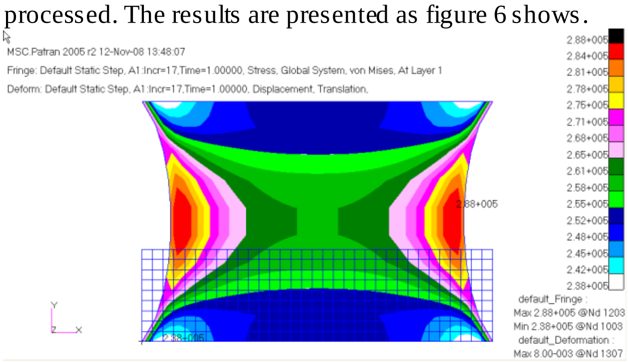

Fig 6, the globe stress of fiber section (meshed rectangle area is the original dimension of sample with thickness of 8.6 micron)

4, SUMMARY

Pure polyurethane solution is electrospun and 5 samples with different thickness were collected. Scanning electron microscopy was used to determine the thickness of samples. The relationship between the thickness and the mechanical properties of electrospun nanofibers mat of polyurethane has been investigated with tensile testing. FEM simulation is performed to simulate the distribution of stress when the sample is elongated. The experimental result shows that the maximum load increases when the thickness increases. Thus, in order to get more robust and reliable nanofibers mat, it is recommended to increase its thickness to an optimum dimension to fulfill the requirement of potential application.

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