World Academy of Science, Engineering and Technology
International Journal of Mechanical and Mechatronics Engineering
Vol:9, No:4, 2015

Optimum Design of Attenuator of Spun-Bond Production System

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***Abstract*—**Nanofibers are effective materials which have frequently been investigated to produce high quality air filters. As an environmental approach our aim is to achieve nanofibers by melting. In spun-bond systems extruder, spin-pump, nozzle package and attenuator are used. Molten polymer which flows from extruder is made steady by spin-pump. Regular melt passes through nozzle holes and forms fibers under high pressure. The fibers pulled from nozzle are shrunk to micron size by an attenuator; after solidification, they are collected on a conveyor. In this research different designs of attenuator system have been studied; and also CFD analysis has been done on these different designs. Afterwards, one of these designs tested and finally some optimizations have been done to reduce pressure loss and increase air velocity.

***Keywords*—**Attenuator, nanofiber, spun-bond.

I. INTRODUCTION

AS a nanofiber production method, electrospinning has intensively been investigated recently. But lots of solvent are used in traditional electrospinning method which reduces production rate. Moreover, this method increases production costs. Therefore, melting system is invented as a basic method for SNS nanofiber layer fabrics. In this system, extruder, nozzle package and high-voltage power supply are essential devices. Mixture or molten polymer is put in a feeder which has one or more holes. In this process polymer granules are fed by feeder which are melted and moved on by extruder. After extruder, granules are driven to a nozzle which has numerous holes and are converted to fibers. Coat- Hanger die has been designed and selected to be used in this research. Coat- Hanger die primitive design has been done by an analytical method [1]. To finalize the design a method has been used inversely [2]. Coat- Hanger die is shown in Fig. 1.

Finalized design of nozzle has been manufactured and mounted on extruder. This situation is shown in Fig. 2. There are 2 heaters on broad surfaces of nozzle which have a total power of 1300 W.

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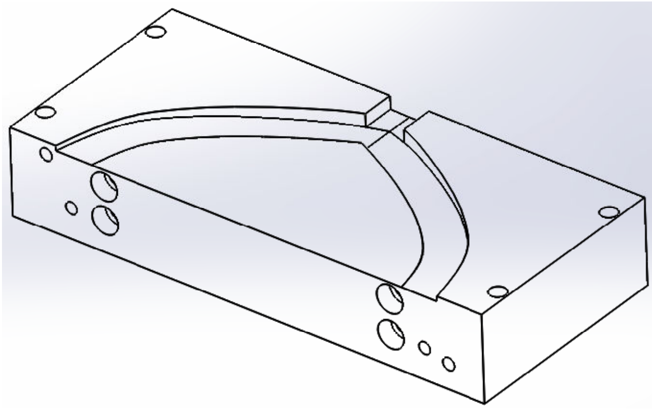

Fig. 1 Coat- Hanger die design

Fig. 2 Coat- Hanger die mounted on extruder and produced fibers

After nozzle, molten polymer is solidified by cold air [3], [4]. In attenuation region fibers are attenuated by high speed air. Depending on the polymer characteristics and production rate, air velocity reaches 1000 to 8000 m/min [5], [6]. For instance, polypropylene (PP) usually needs a 2000 m/min velocity where this amount is about 4000 m/min for polyamide (PA). Through cooling and protracting process, parameters such as humidity and temperature should be controlled.

Fibers diameter and its homogeneity are two main factors which determine performance of produced filter [7]. In order to achieve this goal polymer pressure in the nozzle and also air pressure distribution at jet section must be equal [8].

II. Attenuator Design and CFD Analysis

By inspecting so many different references and patents a primitive design for attenuator has been developed. The design should be done at a state which guaranties high speed with lowest vibration. Vibration is an important factor in attenuator design; it results in agglomerated nanofibers and subsequently non-uniform fabrics [9].

As is shown in Fig. 3, air partitions are mounted at the top of attenuator unit which has 8 numbers of partitions. These partitions guarantee a smooth pacing near jet. Also a 10 mm gap has been made after partitions to serve as a jet to make a high speed flow which is intended to protract and cool nanofibers. This gap is shown in Fig. 4. There is a hat shaped part on attenuator unit which has the functionality of air driving to make a smoother flow of air stream; it avoids turbulence and consequent vibrations [10]. Also attenuator inlet in this design is a hole with 25 mm of diameter.

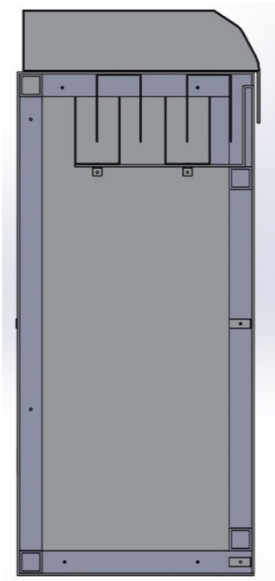

Fig. 3 Attenuator air partitions

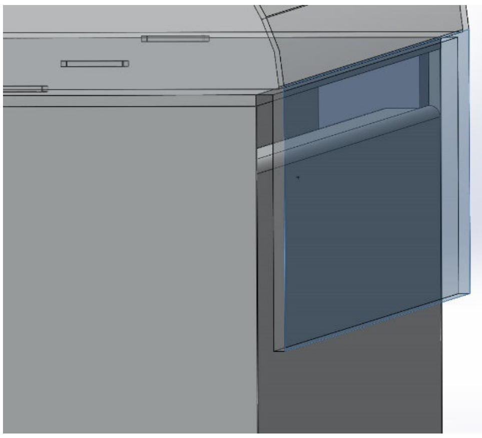

Fig. 4 Attenuator jet gap

Selected design has been drawn and meshed in ANSYS-ICEM CFD. The mesh method which has been used in this process is a very accurate one which uses blocks instead of automatic meshing. Afterwards, this mesh has been inserted into FLUENT and calculated. Input boundary condition is 0.07 bar which has been obtained by trial and error. Fluent results for velocity in Y- direction and pressure are shown in Figs. 5 and 6 respectively. As results show, air speed near the jet is about 34m/s.

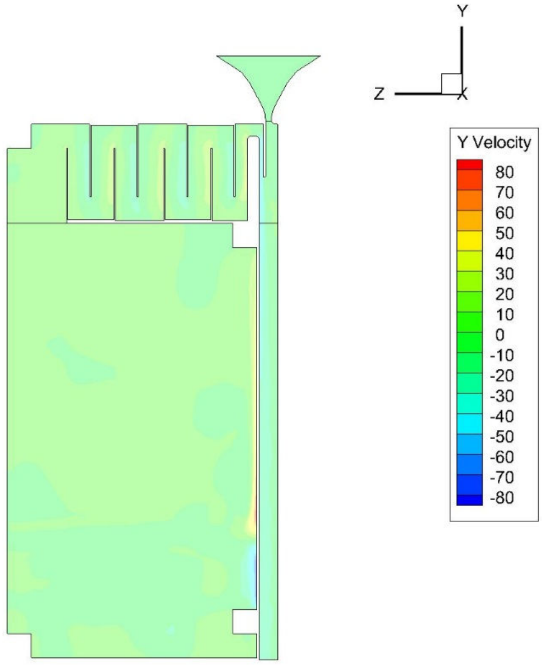

Fig. 5 Attenuator simulation velocity results

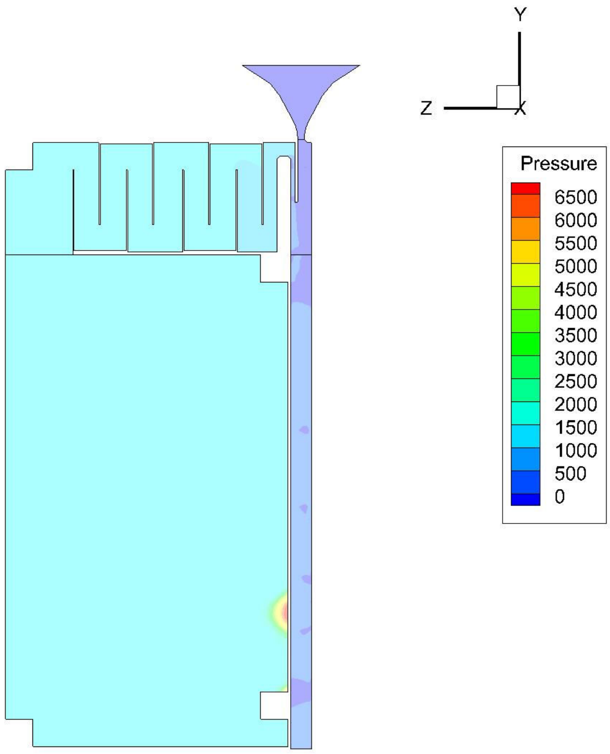

Fig. 6 Attenuator simulation pressure results

III. Results Validation

Selected design has been manufactured and a fan with 0.07 bar output pressure has been purchased in the sake of experiments. Table I shows fan specifications.

TABLE I
PURCHASED FAN SPECIFICATIONS

Power (kW)	Output Pressure (Pa)	Flow- rate (m^3/h)
7,5	7000	4000

Manufactured attenuator has been mounted on the fan as shown in Fig. 7 and jet velocity tests have been done on it.

Fig. 7 Attenuator mounted on fan

Comparison of test and CFD results is shown in Table II.

TABLE II
COMPARISON OF TESTS AND SIMULATION RESULTS

Type	Jet Speed (m/s)
Experimental Test	34
Simulation	31

As is obvious in Table II there is a very close overlapping between experimental and simulation results where max deviation is 8%. Therefore, some optimizations could be done on the basis of simulation results.

However, sometimes there would be needs for higher speeds which will requests fans with higher output pressure and subsequently higher powers. In this situation, demanded fan will be very large and expensive. So it's needed to obtain higher speeds with lower pressure loss by doing some optimizations on attenuator interior design which affects pressure loss significantly. This process is described in following section.

IV. Optimizations

As explained in last section it's needed to reduce power loss in attenuator unit. Therefore some researches has been done on this matter and a new interior design has been developed. This process should be done on a layout which guarantees smooth narrowing throughout air path; so the least possible amount of power loss will be obtained. In this process, to reduce pressure loss, a larger input has been selected which is as large as fan output; also interior design has been made in a case which has a smooth narrowing layout. Air partitions have been made vertical and by using longer partitions in every path smooth narrowing made possible. Moreover, last path which drives air to jet has an angle of 5 degrees; this path starts with 18 mm width and ends in a 5 mm jet gap. There was a significant pressure loss because of sharp exit on jet; so it has been changed to a 45 degrees exit on bottom edge of jet gap. Finally a simulation with the same properties of former one has been done on this layout. CFD analysis for velocity in Y –direction and pressure results are shown in Figs. 8 and 9 respectively. Again inlet pressure here is 0.07 bar.

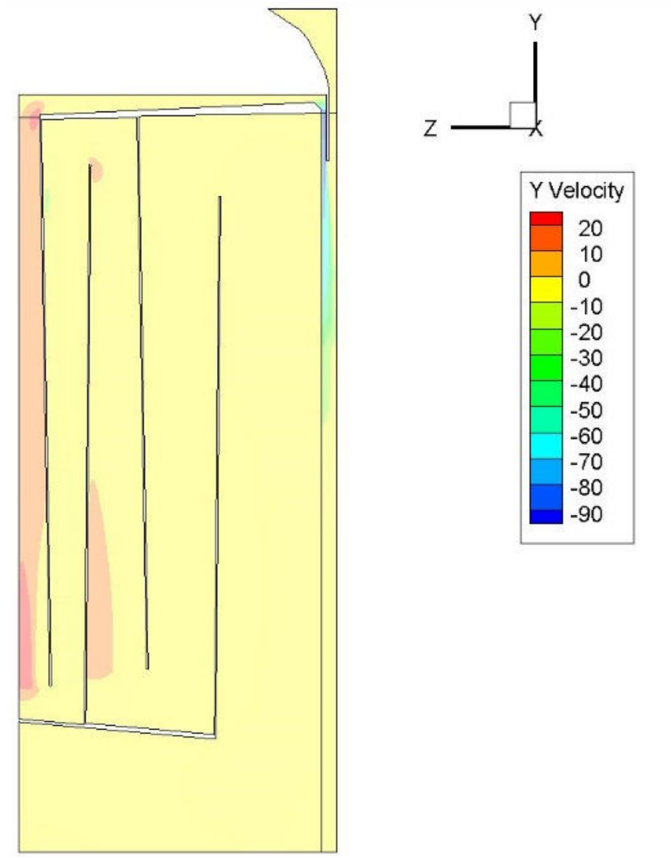

Fig. 8 Simulation velocity results for optimized attenuator design

As are shown in figures, by using same inlet properties, there is a 60 m/s growth in jet velocity which is about 90 m/s. Also pressure losses at the wall next to inlet and jet have been eliminated.

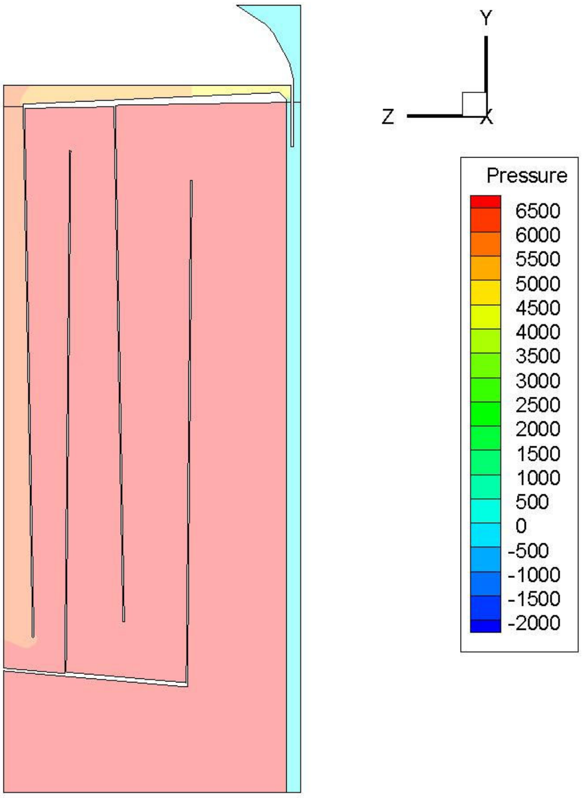

Fig. 9 Simulation pressure results for optimized attenuator design

V. Conclusion

There was a large amount of pressure losses at interior part of attenuator unit which have been reduced significantly by changing some design parameters. Also by using the same properties of inlet a 3 times larger amount of velocity has been obtained at jet section which will help to protract nanofibers more than before. Also by using smooth narrowing method at interior part there will be less vibration which will help to obtain more uniform spun-bonds.

Acknowledgments

We gratefully acknowledge the financial support of The Scientific and Technological Research Council of Turkey (TUBITAK), through grant number: 112M311.

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