Fibers Presence Effects on Air Flow of Attenuator of Spun-Bond Production System

Nasser Ghassembaglou, Abdullah Bolek, Oktay Yilmaz, Ertan Oznergiz, Hikmet Kocabas, Safak Yilmaz

Abstract—Different designs of attenuator systems have been studied in this research; new analysis have been done on existed designs considering fibers effect on air flow; it was comprehended that, at fibers presence, there is an air flow which agglomerates fibers as a negative effect. So some new representations have been designed and CFD analysis has been done on them. Afterwards, one of these representations selected as the most optimum and effective design which is brought in this paper.

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

I. Introduction

HIGH quality air filters production using nanofibers, as a functional material, has frequently been investigated. As it is more environmentally friendly, melting method has been selected to produce nanofibers. Spun-bond production systems consist of extruder, spin-pump, nozzle package and attenuators. Spin-pump makes molten polymer steady, which flows through extruder. Fibers are formed by regular melts passing through nuzzle holes under high pressure. Attenuator prolongs fibers to micron size to be collected on a conveyor [1]. Intensive investigation of electrospinning as a nanofiber production method has been done recently. In traditional electrospinning method, lots of solvent is used which reduces production rate. Beside of it, this method increases production expenses. Therefore, in order to produce SNS nanofiber layer fabrics, melting system was invented as a fundamental method. Extruder, nozzle package and high-voltage power supply are essential devices in this system. A feeder, which has one or more holes, is used to add mixture or molten polymer. A funnel is used to feed polymer granules, which are melted and moved on by extruder. After extruder, granules are forwarded to a nozzle which has numerous holes; they are converted to fibers using this nozzle. A Coat- Hanger die could be used as nozzle [1]. This die is shown in Fig. 1.

The nozzle should be mounted on an extruder to produce molten fibers. This situation is shown in Fig. 2. Broad surfaces of nozzle encompass two heaters which have a total power of 1300 W [1].

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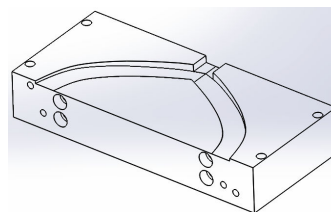
Fig. 1 Coat- Hanger die design [1]

Fig. 2 Coat- Hanger die mounted on extruder and produced fibers [1]

After nozzle, cold air solidifies molten polymer [2], [3]. High speed air attenuates fibers at attenuation region. Air velocity reaches 1000 to 8000 m/min depending on polymer characteristics and production rate [4], [5]. For instance, a velocity of 2000 m/min is usually used for polypropylene (PP) where this amount is about 4000 m/min for polyamide (PA). Parameters such as humidity and temperature should be controlled through cooling and protracting process.

Quality of produced fibers is depended on two main factors which are fibers diameter and its homogeneity [6]. Achieving this goal is strongly related to uniformity of polymer pressure in nozzle and air pressure distribution at jet section [7].

II. Attenuator Design Selection and CFD Analysis

A design for attenuator has been chosen by inspecting so many different references and patents. High speed with lowest vibration should be guaranteed at selected design. Vibration is an important factor in attenuator design; Agglomerated nanofibers and subsequently non-uniform fabrics are results of vibration [8].

As is shown in Fig. 3, air partitions are vertically mounted into attenuator, which have slight angles to let the air flow smoothly through narrowing passage. There are five numbers of partitions here and a narrowing gap which leads the air to jet. These partitions guarantee a smooth pacing near jet. Also a 5 mm gap has been represented after partitions to serve as a jet to make a high speed flow which is intended to protract and cool nanofibers [1].
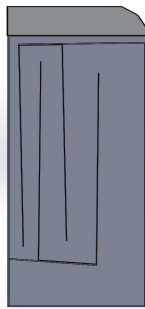
Fig. 3 Attenuator air partitions [1]

Fig. 4 shows the assembly of two attenuators; all of analysis results in this paper are shown in a mid-section between two attenuators which is shown in this Fig. 1.

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 0.2 kg/s of air, which has been obtained by trial and error. By this, desired velocities could be obtained at jet and exit sections of attenuator. Analysis results of velocity in Y and X directions and pressure are shown in Figs. 5, 6 and 7 respectively. As results show, air speed at exit section is about 60 m/s. Also its velocity at jet section is about 130 m/s which is a desired velocity; also, in absence of fibers, there isn't any inward air flow to wonder about. Air flow vectors are shown in Fig. 8. But adding fibers to this analysis shows a negative effect of fibers presence on air flow which induces an inward air flow; this is desired to disperse fibers at exit section of attenuator to have more uniform fabrics. This inward flow will agglomerate fibers which are in contrary with project desire.
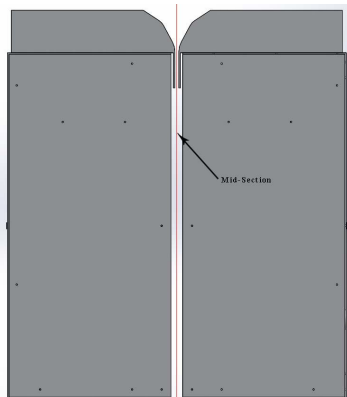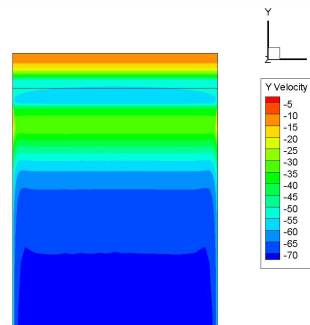

Fig. 4 Attenuators assembly

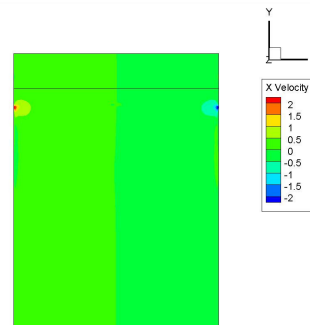Fig. 5 Attenuator simulation Y velocity results

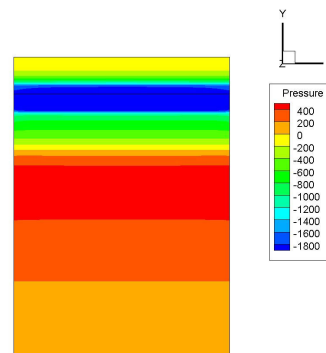Fig. 6 Attenuator simulation X velocity results

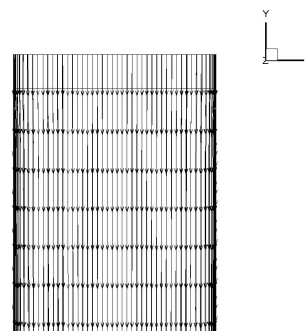

Fig. 7 Attenuator simulation pressure results

Fig. 8 Air flow vectors of attenuator

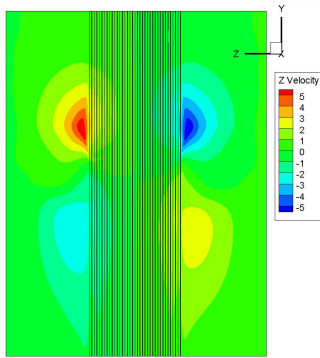This negative effect is shown in Fig. 9 which contours velocity at X direction.

Fig. 9 Simulation X velocity results of attenuator containing fibers

As is obvious, there is a speed of 5 m/s at mid-section of attenuator which tends to collect fibers at their central axis. This negative velocity is conspicuous in Fig. 10 too, which shows flow vectors. Also, in the sake of comparisons, a contour plot which shows Y velocity at this situation is brought in Fig. 11. This problem would be solved using different methods; in order of this, some changes have been suggested and all of them are analyzed using CFD methods. Results are shown in following section.
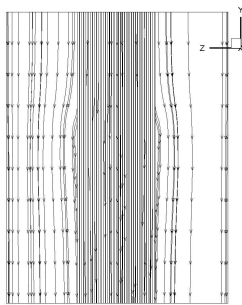

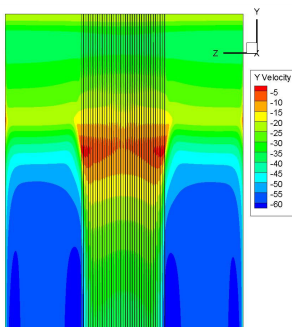Fig. 10 Air flow vectors of attenuator containing fibers

Fig. 11 Y velocity contours of attenuator containing fibers

III. CFD ANALYSIS RESULTS AND PROBLEM SOLUTION

It was suggested to make some holes on attenuator side walls to solve the mentioned problem; some primitive guesses have been done on this issue and three different holes considered on attenuator unit side walls; these representations

have been analyzed through CFD programs and results are explained as followings.

At first stage, it was suggested to make two circular holes with a diameter of 6 mm on attenuator side walls; these holes were created at a distance of 20 cm from attenuator base. Results are shown in Fig. 12. As is obvious, these holes can reduce the negative velocity to its 20 percent; but can't eliminate it thoroughly. Also as shown in Fig. 13 they don't affect Y velocity.
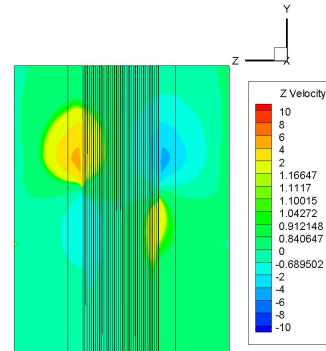

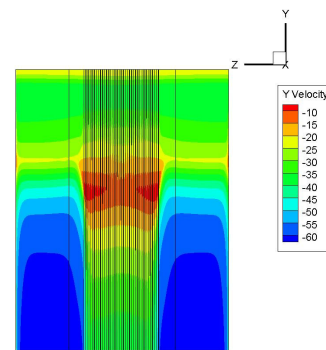Fig. 12 Z velocity contours of attenuator with two circular holes on both sides

Fig. 13 Y velocity contours of attenuator with two circular holes on both sides

At second stage it was suggested to change the shape of holes to squares and also lowering their position to a distance of 19 cm from the base of attenuator. Using these holes didn't provide a solution for explained problem and the effects of it was as like as circular holes. Next, it was suggested to raise square holes higher in altitude for about 18 mm. The properties of squares are as same as previous ones. The results of heightened square holes were as like as others, which didn't solve confronted problem. Afterwards as a final suggestion two rectangular gaps with a height of 20 cm and a width of 4 mm have been created on side walls. The results for this representation are shown on Figs. 14 and 15. As seen here, this solution don't solve mentioned problem too. Moreover, it affects Y velocity in an adversary way, where this velocity reduces to 50 m/s near exterior parts of fibers. So neither of these solutions, which were based on creating different gaps on side walls, made a proper change on undesirable inward

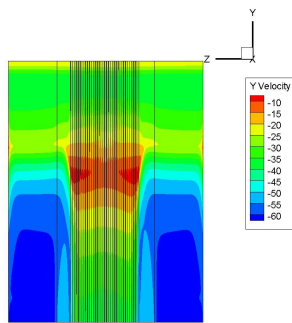velocities; thus a different solution has been proposed as coming in following section.

Fig. 14 Y velocity contours of attenuator with two large rectangular gaps on both sides
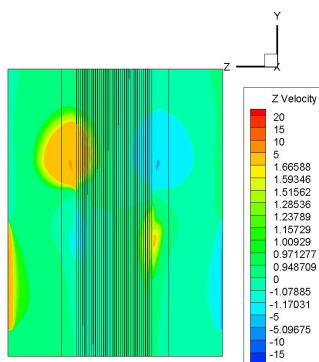

Fig. 15 Z velocity contours of attenuator with two large rectangular gaps on both sides

IV. OPTIMIZATIONS

Since any combination of holes wasn't effective in lowering negative inward velocities, a new representation of attenuator design should be considered. So wall effects were taken into account and it was comprehended that after adding fibers to air passage volume, it reduces air passing hydraulic diameter; and as a result, air tends to move inwardly to fibers central axis. Therefore, it has been suggested to enlarge attenuator width smoothly through air passage. This enlarging space, starts from jet section and ends at attenuator base. These changes on geometry have been done using ICEM-CFD geometry tools and again analyzed using FLUENT. The results are shown in Figs. 16 and 17. Input parameters are as like as previous analysis; it will guarantee a realistic comparison between different analysis. As shown here, all negative inward velocities are eliminated thoroughly and air is moving in desired direction, which is outward. These directions are shown in Fig. 18. Also it doesn't affect air velocity at Y direction, which is one of the most important factors in attenuator design.
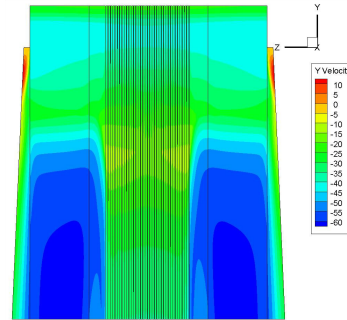

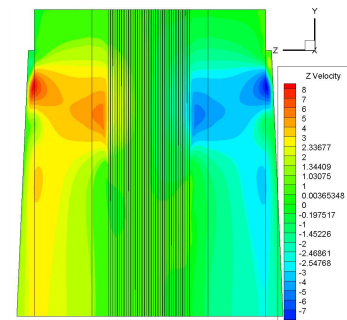Fig. 16 Simulation Y velocity results of enlarging attenuator design

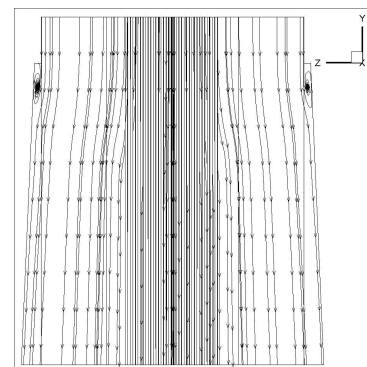Fig. 17 Simulation Z velocity results of enlarging attenuator design

Fig. 18 Air movement direction vectors of enlarging attenuator design

V. CONCLUSION

Adding fibers to attenuator air passage brought an inward velocity of air flow into account, which was undesired. This inward velocity could agglomerate fibers and prevent production of uniform fabrics. So different solutions for this issue have been researched through CFD analysis; the best solution was to enlarge air passage space after jet section; this enlarging space eliminates undesired air velocities. Moreover, it provides an out warding air flow, which guarantees fibers dispersion at attenuator exit; this desiderated flow will help to produce fibers with a random uniformity.

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