Effect of Spinning Conditions on Web Properties of PP/ZrO_2 Spunbond Nonwovens

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1. Introduction

Spunbond nonwovens have been concerned with the commercial and scientific interests, owing to the simple process for manufacturing, the abundant raw materials and the many end-use products(1,2). The spunbond process is defined as a nonwoven manufacturing system involving the direct conversion of a polymer into continuous filaments and integrating with the conversion of the filaments into a random-laid, bonded nonwovens(3). A variety of spunbond nonwovens is engineered by manipulating the process conditions and by adding the functional additives.

The web properties of spunbond nonwovens are highly dependent on the processing conditions, such as spinning temperature, cooling conditions and the bonding temperature and bonding pressure of web(4-9). Thus, it is basically necessary to study the relationships between the various spunbond processing conditions and the properties of raw materials. The main characteristic of zirconium dioxide(ZrO_2) has been given the activated heat by a far infrared radiation. It can be applied on manufacturing spunbond nonwovens, and improved thermal property by dispersing or mixing it with the original polymer and making continuous filaments through the extruder on the spinning process.

In this work, we have studied the final filament diameter, mechanical properties and crystallinity of PP/ZrO_2 fibers. Also, The effect of processing conditions such as spinning temperature, throuhgput rate and cooling conditions on web properties of PP/ZrO_2 spunbond nonwovens has been investigated.

2. Experimental

Isotactic polypropylene(PP, FR160 Honam Phetrochemical Inc., MI=15.0) and zirconium dioxide(ZrO_2, Yakuri Pure Chemical Co.,) were used as the raw materials. The production of PP and PP/ZrO_2 spunbond nonwovens was controlled with four different operating conditions, i.e., filament extrusion, drawing down, lay down and bonding, which is modified melt spinning system owned by our laboratory. The spunwebs are manufacture with several processing conditions as follows:

(1) The spinning temperature; spunwebs were made at the spinning temperature ranged from 200℃ to 230℃ in increments of 10℃. The primary air pressure and polymer throughput rate were 0.1kg/cm^2 and 0.85g/min/hole, respectively and the other

processing conditions were held constant.

(2) The air pressure; the spunwebs were made at the auxiliary air pressure ranged from 1kg/cm^2 to 4kg/cm^2 with the 230℃ melting temperature to achieve the minimum fiber diameter and to increase drawing effects. The primary air pressure was 0.1kg/cm^2 and the others were constant levels.

(3) The polymer throughput rate; spunwebs were prepared at the throughput rate varied from 0.85g/min/hole to 1.05g/min/hole in increase of 0.05g/min/hole. The throughput rate was controlled through the revolution of the extruding screw and gear pump. The melt temperature and the axiliary air pressure were kept at 230℃ and 4kg/cm^2 levels, respectively.

Table 1. The processing conditions of PP and PP/ZrO_2 fibers.

processing condition / sample run no.			melt temperature(℃)	primary air pressure (kg/cm^2)	auxiliary air pressure (kg/cm^2)	polymer throughout rate (g/min/hole)
material	PP	1	200	0.1	4	0.85
		2	210	0.1	4	0.85
		3	220	0.1	4	0.85
		4	230	0.1	4	0.85
		5	230	0	0	0.85
		6	230	0.1	0	0.85
		7	230	0.1	1	0.85
		8	230	0.1	2	0.85
		9	230	0.1	3	0.85
		10	230	0.1	4	0.95
		11	230	0.1	4	1.05
	PP/ZrO_2	12	200	0.1	4	0.85
		13	210	0.1	4	0.85
		14	220	0.1	4	0.85
		15	230	0.1	4	0.85
		16	230	0	0	0.85
		17	230	0.1	0	0.85
		18	230	0.1	1	0.85
		19	230	0.1	2	0.85
		20	230	0.1	3	0.85
		21	230	0.1	4	0.95
		22	230	0.1	4	1.05

Table 1 shows the processing condition of PP and PP/ZrO_2 fibers. In order to evaluate the effect of processing conditions on the spunweb properties, we have investigated the tensile properties, density and basic weight of the PP and PP/ZrO_2 spunbond nonwovens, and we examined the final fiber diameter, thermal properties and crystallinity of PP and PP/ZrO_2 fibers to estabilish optimum processing conditions with respect to web properties.

3. Results and discussion

Fig. 1 shows the effect of the spinning temperature on the final fiber diameter. The final fiber diameters of PP and PP/ZrO_2 fibers have decreased with the increasing in the spinning temperature at the throughput rate of 0.85g/min/hole. As spun at 230℃, the final fiber diameter of PP is 298μm and its of PP/ZrO_2 is 305μm. The results were caused that at higher spinnig temperature, the local stress needed to draw down the fibers is less and consequently, the fiber is drawn down more.

Fig. 2 shows the effect of the spinning temperature on the breaking stress of PP and PP/ZrO_2 fibers. As shown in Fig. 2, the stress at break increased to some extent with the increasing in the spinning temperature. From the above results, it is evident that the increase of the breaking stress is attributed to the increased orientation of molecular chains by drawing down PP and PP/ZrO_2 fibers. The stress of PP/ZrO_2 fiber at break increased less with the increasing in the spinnig temperature than its of PP fiber. This results are caused by discontinuity in stress transfer or stress concentration at the interface between the zirconium dioxide and polypropylene during drawing process.

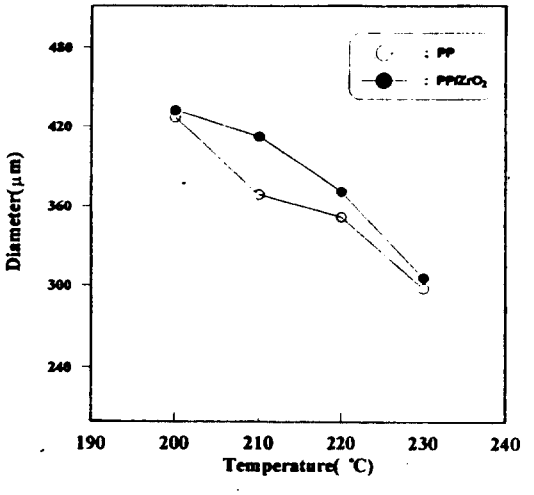

Fig. 1. The diameter of PP and PP/ZrO_2 fibers on various temperature.

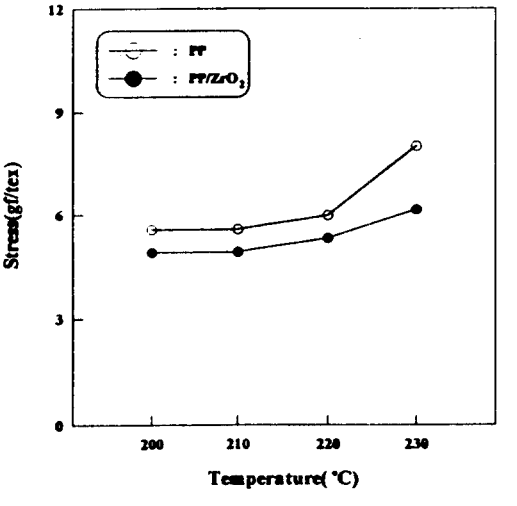

Fig. 2. The breaking stress of PP and PP/ZrO_2 fibers on various temperature.

Fig. 3 shows the effect of the auxiliary pressure on the crystallinity of PP and PP/ZrO_2 fibers. The results shown in Fig. 3 indicated that increasing the auxiliary air perssure up to 4kg/cm^2 resulted in increasing the crystallinity of PP and PP/ZrO_2 fibers. But the crystallinity of PP/ZrO_2 fibers is somewhat lower than that of PP fibers,

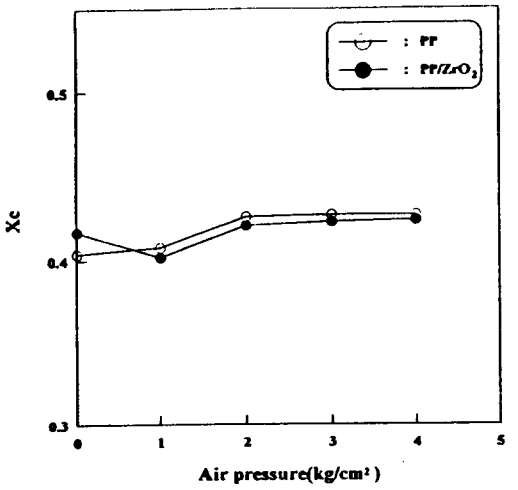

Fig. 3 . The crystallinity of PP and PP/ZrO_2 fibers on various air pressure.

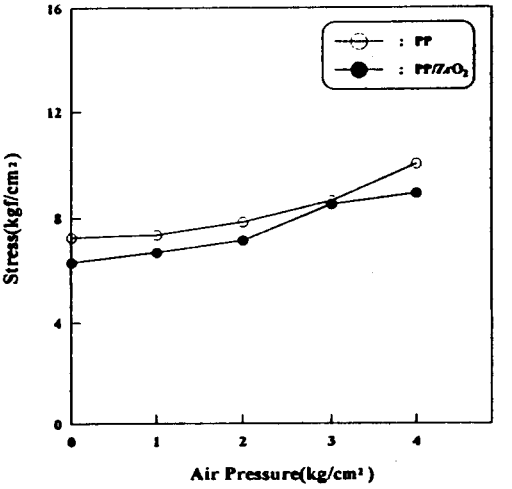

Fig.4 . The breaking stress of PP and PP/ZrO_2 nonwovens on various air pressure.

because of adding ZrO_2 to PP matrix. The effect of the auxiliary air pressure on the stress of PP and PP/ZrO_2 spunbond nonwovens at break is presented in Fig. 4.

The breaking stress of PP and PP/ZrO_2 spunbond nonwovens at break has increased with increasing the auxiliary air pressure. This result corresponds to its of Fig. 3. The result is considered that as higher auxiliary air pressure, the final fiber diameter becomes finer and the density of PP and PP/ZrO_2 spunbond nonwovens has increased and the number of the bonding point of fibers laid down randomly in PP and PP/ZrO_2 webs was increased. From this result it is obvious that the auxiliary air blowing is considerably influenced on the webs properties of PP and PP/ZrO_2 spunbond nonwovens.

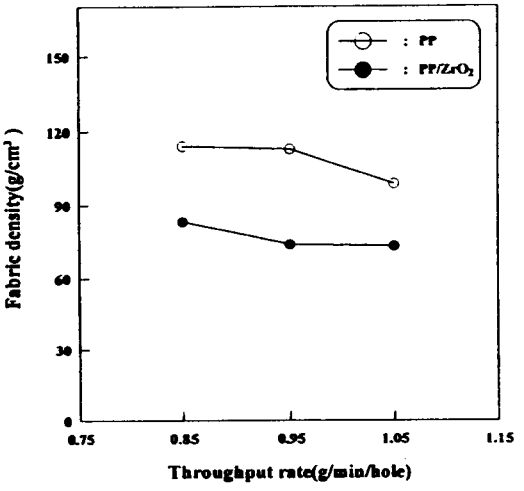

Fig.5 . The fabric density of PP and PP/ZrO_2 fibers on various throughput rate.

Fig. 5 shows the effect of the throughput rate on the density of PP and PP/ZrO_2 spunbond nonwovens. As the throughput rate was increased to 1.05g/min/hole, the density of PP and PP/ZrO_2 spunbond nonwovens has decreased. When the throughput rate increased, the fiber cooled more slowly along the spinline and the die swell has increased, according the increasing of the die entrance pressure and the starting diameter is larger compared to the lower throughput rate. Therefore, the number of fiber laid down in a random manner gets so far more in case of the fine fiber diameter than the thicker fibers with web formation.

Table 2 shows the melting temperature and crystallization temperature with various throughput rate measured by differential scanning calorimeter. It appears that the different throughput rate is scarcely influenced on the melting temperature and the crystallization temperature. The result is only obtained that the crystallization temperature of PP/ZrO_2 fiber comes up higher somewhat than its of PP fiber.

Table 2. The melting and crystallization temperature of PP and PP/ZrO_2 fibers on various throughput rate.

throughput rate (g/min/hole)	PP filament		PP/ZrO_2 filament	
	Tm(℃)	Tc(℃)	Tm(℃)	Tc(℃)
0.85	159.5	101.7	159.0	103.6
0.95	160.7	100.0	159.8	103.2
1.05	160.8	101.4	159.3	103.2

4. Conclusion

In order to characterize the web properties of PP/ZrO_2 spunbond nonwovens, we have developed the manufacturing process of PP/ZrO_2 spunbond nonwovens by changing melt spinning system owned by our laboratory. From the study of the effect of spinning conditions on the web properties of PP/ZrO_2 spunbond nonwovens, the results were as follows:

1) The final fiber diameter of PP and PP/ZrO_2 fibers has decreased to about 70% with the increasing in spinnig temperature from 200℃ to 230℃.
2) As the auxiliary air pressure has increased up tp 4kg/cm^2, the stress of PP and PP/ZrO_2 spunbond nonwovens at break and the crystallinity of PP and PP/ZrO_2 fibers are increased.
3) The density of PP and PP/ZrO_2 spunbond nonwovens has decreased with increasing throughput rate increases up to 1.05g/min/hole and the increase in the

throughput rate has scarcely influenced on the melting temperature and the crystallization temperature of PP and PP/ZrO_2 fibers.

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