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CURRENT AND FUTURE TRENDS IN POLYMERIC MATERIALS

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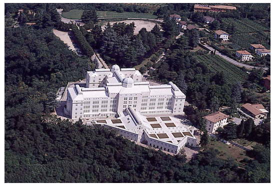
STRUCTURAL AND MECHANICAL CHARACTERIZATION OF ORIENTED POLYPROPYLENE (FIBERS AND WOVEN NONWOVEN FABRICS)



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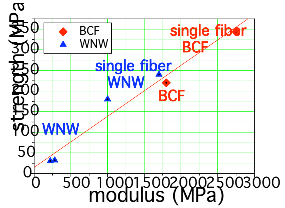


Fig. 1. Mechanical properties of WNW fabrics, BCF multifilament and single fibers.

INTRODUCTION

Polypropylene represents one of the more worldwide used plastics with a large variety of products and applications. As usual for semicrystalline polymers, the properties of PP products strictly depend on the processing (fiber spinning, film extrusion, injection, …), where orientation and crystallization phenomena are involved. Object of this communication is the mechanical and structural characterization of oriented PP products, i.e. commercial Bulk Continuous Filament (BCF) and Woven Nonwoven fabrics (WNW) by using DSC, DMTA, tensile measurements and XRD analysis. In particular, a recent methodology to analyze diffraction images of oriented polymers to obtain crystal structure, texture and microstructural information is presented. The higher the orientation, the higher the mechanical properties, and the sharper the texture, as revealed by the structure refinement approach including a Rietveld Texture Analysis. A quantitative texture analysis has been also developed and successfully applied to oriented PP blends.

EXPERIMENTAL

Differential scanning calorimetry was performed by means of a Mettler DSC30 calorimeter in thermal cycle between 0 and 200°C with a heating/cooling rate of $\pm$10°C/min.

Tensile test was performed on BCF multifilaments (200 mm length) and WNW fabrics (50 mm width and 200 mm length) by using a dynamometer Instron mod. 4502 with a cross-head speed of 100 mm/min. WNW fabrics were tested both in machine (MD) and in cross direction (CD). Single fibers of 10-20 mm were tested with a crosshead of 5-10 mm/min.

Isothermal creep at 25°C was performed on samples 200 mm length (and 50 mm width of WNW fabrics) by applying a constant stress for 30 minutes and a following recovery of 30 minutes at a minimum stress of 1.5 and 0.05 MPa for BCF and WNW respectively. WNW fabrics were tested both in machine (MD) and in cross direction (CD).

DMTA-Thermal creep
Specimens of BCF (15 mm length) and WNW (stripes 20x5mm) were undergone to dynamical mechanical analysis in tensile mode by using a DMTA Mk II (Polymer Laboratories) with dynamic deformation 11 micron, frequency of 5Hz, static stress between 1-16 MPa and heating rate of 3°C/min in the range –50/120°C.
Thermal creep TC was evaluated according to the equation TC= 100*(DL/L_0), where DL is the specimen length variation and L_0 is the initial length.Storage (E’) and loss (E”) moduli were also reported.

PRODUCTS

Bulk continuous filament (BCF, 1150 dtex, 64 filaments; equivalent diameter 403 micron) were industrial produced by Aquafil Spa (Arco, Italy) by using PP with melt flow of 10 g/10 min (2.16 Kg, 230°C).

Woven non-woven fabrics (WNW, 80 g/m^2) were spunbonded by Texbond (Rovereto, Italy) by using PP with melt flow of 10 g/10 min (2.16 Kg, 230°C).

product		I SCAN [0°C – 220°C] Tf [°C]	–ΔH [J/g]	%	II SCAN [220°C – 0°C] Tf [°C]	ΔH [J/g]	III SCAN [0°C – 220°C] Tf [°C]	–ΔH [J/g]	%
WNW fabric regular bonded									
WNW-r	As received	173.5	81.8	39.1	117.8	91.5	164.5	93.8	44.9
WNW-r MD (break)	After break	172.5	87.9	42.1	116.7	98.1	165.0	96.7	46.3
WNW-r CD (break)	After break	171.2	82.6	39.5	116.6	94.5	164.7	93.8	44.9
WNW fabric high bonded									
WNW-h MD	As received	175.5	84.6	40.5	121.1	95.2	164.2	96.2	46.0
WNW-h MD (3.5 MPa)	After creep 3.5 MPa	171.6	84.1	40.2	121.5	96.3	163.4	96.6	46.2
WNW-h CD (3.5 MPa)	After creep 3.5 MPa	173.7	84.3	40.3	121.8	95.1	163.6	96.7	46.3
WNW-h MD (16 MPa)	After creep 16MPa	174.7	85.0	40.7	121.9	93.5	164.5	95.1	45.5
WNW-h CD (16 MPa)	After creep 16MPa	172.0	80.0	38.3	121.7	92.3	163.5	93.9	44.9
WNW-h MD (break)	After break	170.1	86.2	41.2	121.8	95.7	163.5	95.8	45.8
WNW-h CD (break)	After break	173.1	80.5	38.5	120.1	93.1	165.1	95.2	45.6
Multifilament fibers									
BCF	As received	175.5	74.6	35.7	114.4	90.9	166.6	91.3	43.5
BCF (16MPa)	After creep 16MPa	172.9	74.0	35.4	115.1	89.4	165.5	90.7	43.4
BCF (78Mpa)	After creep 78 MPa	172.9	79.4	38.0	115.4	89.5	165.5	91.5	43.8
BCF (break)	After break	174.0	108.3	51.8	115.4	89.1	166.0	90.5	43.3

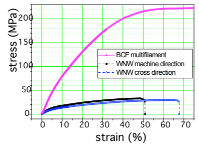


Figure 2. Stress-strain curves of BCF and WNW specimens at room temperature.

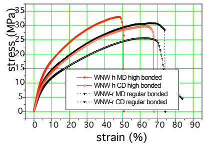


Figure 3. Stress-strain curves at room temperature of high bonded and regular bonded WNW specimens in machine (MD) and cross (CD) direction.

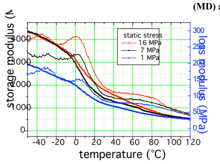


Figure 4. Effect of static stress on E’ and E” of BCF fibers.

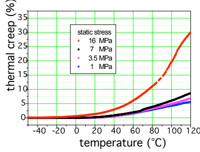


Figure 5. Thermal creep of BCF fiber obtained in DMTA measurements as function of static stress.

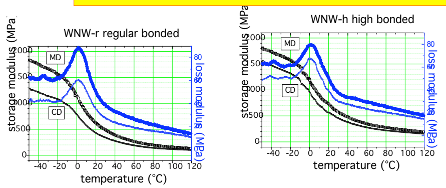


Figure 6. E’ and E” of high bonded and regular bonded WNW fabrics tested in cross direction (CD) and in machine direction (MD).

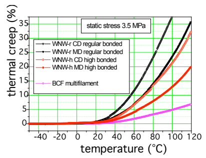


Figure 7. Thermal creep of high bonded and regular bonded WNW fabrics tested in cross direction (CD) and in machine direction (MD).

CREEP MODEL

The following empirical equation (1) has been used to compare the creep results:

$$e(s, t) = K\, s^{m}\, t^{n} \qquad (1)$$

where s and t are the applied stress and the creep time respectively, whereas K, m and n are empirical parameters; in particular m=1 for $s<s_{cr}$ (linearity limit).

The tensile compliance is expressed as

$$D(s, t) = e(s, t) / s \qquad (2)$$

and in log mode

$$\log D(s, t) = \log K + (m-1) \log s + n \log t \qquad (3)$$

In the linearity interval with m=1, the compliance (3) and the creep (1) equations are simplified as follows

$$\log D(s, t) = \log K + n \log t \qquad (4)$$

$$e(s, t) = K'\, t^{n} \qquad (5)$$

where K’ is a constant depending on the stress.

product	applied stress	K	n
BCF multifilament	78 MPa	11.32	0.149
BCF multifilament	16 MPa	2.999	0.097
WNW-r CD regular bonded	3.5 MPa	2.380	0.109
WNW-r MD regular bonded	3.5 MPa	1.808	0.101
WNW-h CD high bonded	3.5 MPa	2.206	0.094
WNW-h MD high bonded	3.5 MPa	1.497	0.080

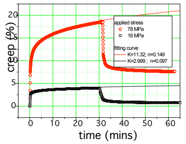


Figure 8. Creep at 25°C of BCF fibers as function of applied stress; continuous lines show the empirical fitting equation.

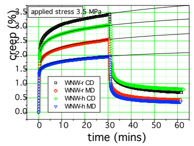


Figure 9. Creep at 25°C of regular (r) and high (h) bonded WNW fabrics tested in cross direction (CD) and in machine direction (MD) at 3.5 MPa of applied stress; continuous lines show the empirical fitting equations.

Polypropylene BCF fibers: XRD analysis

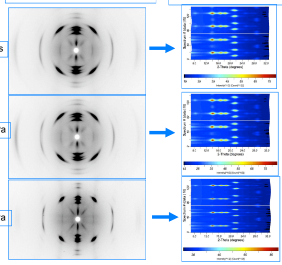
Experimental Transmission Images

Images transformed in spectra and Fitted using Rietveld Texture Analysis

Original fibers

Creep 78 MPa

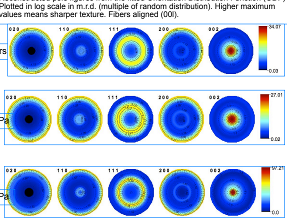
DMTA 16 MPa



Polypropylene BCF fibers: results of Rietveld texture analysis

Reconstructed pole figures from the fitted Orientation Distribution Function (ODF) Plotted in log scale in m.r.d. (multiple of random distribution). Higher maximum values means sharper texture. Fibers aligned (00l).

Fiber dispersion In degrees



	Fiber dispersion In degrees
Original fibers	15.8
Creep 78 MPa	17.9
DMTA 16 MPa	9.1

Note: the creep at ambient temperature does not change significantly the texture. The DMTA at high temperature increase the fiber alignment by 3 times

PP Woven Non-Woven

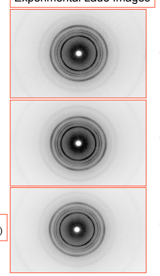
Experimental Laue Images

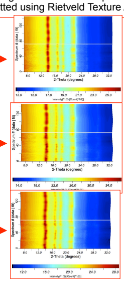
Images transformed in spectra and Fitted using Rietveld Texture Analysis

Original

Machine Direction (MD)

Transverse Direction (CD)





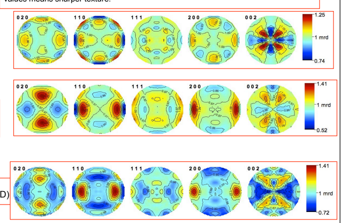
PP Woven Non-Woven: results of Rietveld texture analysis

Reconstructed pole figures from the fitted Orientation Distribution Function (ODF) Plotted in m.r.d. (multiple of random distribution). Higher maximum values means sharper texture.

Original

Machine Direction (MD)

Transverse Direction (CD)



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