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Abrasion Resistance of Ag/SiO_2/PA6 Nanocomposite Fabrics

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In recent decades, polymeric nanocomposites have been widely used in chemical, automobile and aero industries due to their low weight and smoothness. Abrasion resistance is a vital property in variable applications of polymeric composites. Here, to investigate the wear resistance of nylon 6 nanocomposite fabrics, melt spun yarns were filled with different concentrations of Ag/SiO2 nanoparticles and the wear properties of weft knitted nanocomposite and pure samples were evaluated. Results disclosed that the wear resistance of composite fabrics containing nano-particles increased considerably in comparison to pure one. Therefore, nanoparticles can play an important role in improving the nanocomposite wear resistance.

Keywords: Nanocomposites, Nanoparticle, Nanosilver, Nylon 6, Wear Resistance.

PACS numbers: 81.07. – b, 82.35.Np

1. NTRODUCTION

Polymeric materials often show improved mechanical properties if they possess nano-scale structure. Recent studies has been performed on two different regions; composites containing of nano-layers and composites filled with nano-particles [1]. Dasari et al. (2005) investigated the role of nano-clay on the wear characteristics of nylon 6 nanocomposites processed via different routes. It was revealed that the interfacial adhesion of clay to matrix, and not the exfoliated morphology of clay, played a critical role in wear. Exfoliated clay morphology is preferred to aggregate morphology. According to their results the superior wear-performance of nylon 6/organoclay nanocomposite is brought about by a combined effect of fine dispersion of clay platelets in nylon 6, high interfacial interaction between nylon 6 and clay layers, and effective constraint on surrounding nylon 6 material exerted by the clay platelets [1]. In the region of nanocomposites filled with nanoparticles, different researches have been done with variable materials. Sawyer et al. (2003) investigated the wear and friction properties of PTFE filled with different concentrations of 40nm alumina particles. They have found that the wear resistance of this composite increased monotonically with increasing filler concentration and no optimum filler fraction was found [2]. The tribological properties of polyamide 66 (PA66) composites, filled with TiO2 nanoparticles, short carbon fibers, and graphite flakes were investigated by Chang et al. (2005). Sliding tests were performed on a pin-on-disk apparatus under different contact pressures (p), and sliding velocities (v). It was found that nano-TiO2 could effectively reduce the frictional coefficient and wear rate, especially under higher pv conditions [3]. Nanocomposites especially filled with nanoparticles have shown improvement in mechanical properties and wear resistance [3]. Silver nanoparticles have indicated variable advantages such as high antimicrobial potential for modification of polymeric matrices [4]. However, there has not been any research on wear properties of high speed spun multifilament nanocomposite yarns of nylon 6 filled with nanoparticles. This study report the first investigated results of wear properties of nanocomposite fabrics produced from high speed spun multifilament nanocomposite yarns of nylon 6 and Ag/SiO_2.

2. E EXPERIMENTL

2.1 Materials

Nylon 6 chips supplied by Aliaf Company, Iran were used to produce masterbatch and fibers.

Ag/SiO_2 nanoparticles (SiO_2 nanoparticle covered by Ag nanoparticles) produced by Nano group Co., USA were used to produce masterbatch.

2.2 Methods

Masterbatch concentrated by 10 wt% Ag/SiO2 nanoparticles were prepared from mixing of nylon6 chips and nanoparticles by a twin extruder (Brabender, Germany). PA6 chips and the produced masterbatch were dried for 24 h. in vacuum condition at 85 □C. Pure PA6 fibers and the nanocomposite fibers containing 0.20, 0.40, and 0.60 wt% of Ag nanoparticles were prepared, from mixing of virgin PA6 granule and concentrated masterbatch, during melt spinning by an Automatik pilot plant spinning machine (Germany), with the take up speed of 4000 m/min. The produced yarns were drawn by a Zinser D5203 machine (Germany) at temperature of 170 °C and draw ratio of 1.2 [5]. A four-ply yarn, made of four bobbins of each drawn yarn samples, was used to produce weft knitted fabric of each sample.

2.3 Characterizations

Abrasion properties of prepared pure and nanocomposite fabrics were evaluated according to ASTM (D 4966) standard test method using the Martindale machine (Shirley development LTD model).

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3. RESULTS AND DISCUSSIONS

The mass changing of pure and nanocomposite fabrics according to abrasion cycles has been plotted in figure 1. Diagrams changing supposed to be approximately linear and slope varying of each diagram has been shown in figure 2. Slope variations and abrasion cycles to reach tear point of different samples has been reported in Table 1. As shown in figure 1 and 2, abrasion resistance of nanocomposite samples compared to pure one has been significantly improved. This improvement in samples containing 0.02 of Ag nanoparticles was 216.9 %. In addition, the slope variations of different sample diagrams indicated the decline of abrasion speed which caused abrasion properties improvement in nanocomposite samples as compared to pure one. In fact abrasion speed of pure sample is 10 times more than sample with 0.02wt% of Ag nanoparticles. According to the result of our previous research [5], this sample has the highest modulus in comparison to other ones. Investigation of tensile properties in drawn yarn of this sample has also shown that its elongation and flexibility is good and has not been significantly changed.

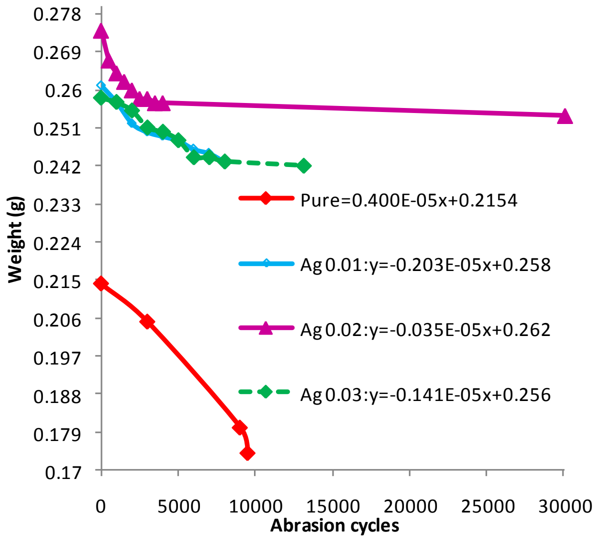

Fig. 1 – The weight of pure and nanocomposite fabrics versus abrasion cycles

In fact, modulus and rigidity increasing caused by improvement the connection between filler and metal surface can result in increasing wear resistance of nanocomposites. In this research, wear resistance variations were corresponded to drawn yarn modules which was used in knitted nanocomposite fabrics. Increasing of crystallinity, dependent on sample flexibility, can be positive or negative and meet an optimum point. While the sample flexibility is suitable to compensate the fabric tension during abrasion, increasing the crystallinity would be positive and prevent fabric folding under wear test.

Consequently, results showed that sample containing 0.02 wt% of nanoparticle improved significantly the wear resistance (216.9% as compared to pure sample).

On the whole, the effect of nanostructure materials on increasing nanocomposite wear resistance is proved by improving fabric mechanical and/or chemical properties [6].

Table 1 – Wear properties of different samples

Samples	Weight reduction speed (g/cycle)	Tear point (cycles)	Tear point variations as compared to pure sample (%)
Pure	0.413×10^{-5}	9500	0.0
Ag 0.01	0.203×10^{-5}	8000	-15.8
Ag 0.02	0.035×10^{-5}	30101	216.9
Ag 0.03	0.141×10^{-5}	13102	37.9

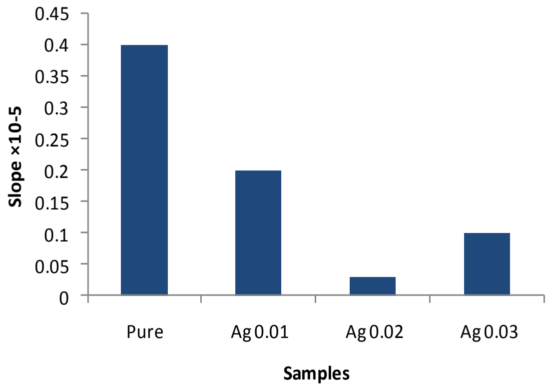

Fig. 2 – The slope variation of different sample diagrams

Another factor influencing wear resistance of nanocomposite fabrics can be heat conduction increasing due to high heat conduction of metal nanoparticles as compared to polymeric matrix.

In fact, the friction between abradant and fabric surface produces considerable heat during abrasion. Silver nanoparticles have high heat conduction in comparison with polymer matrix. Therefore, the nanoparticles can compensate the heat producing and delay fabric destruction. However, increasing nanoparticle ratio can cause some agglomeration, decreasing the rate of heat conduction due to the reduction of special surface of nanoparticles. In this study, the wear resistance properties of Ag/SiO_2/PA6 nanocomposite fabrics has been evaluated. To this end, multifilament nanocomposite yarns containing 0.01, 0.02, 0.03 wt% Ag nanoparticles were prepared from mixing of nylon6 chips and masterbatch during melt spinning. Spun yarns were drawn and finally weft knitted. The prepared fabrics were abraded until reaching the tear point and wear resistance of all samples were reported. Results indicated that sample with 0.02 wt% of Ag nanoparticles has the best improvement of wear resistance in comparison with pure sample (about 217%). This can be provided by high heat conduction of nanosilver particles as compared to polymer matrix, increasing of modulus and increasing of nanocomposite crystallinity preventing fabric folding during abrasion test. Therefore, PA6 nanocomposite fabrics containing Ag/SiO_2 nanoparticles can offer high wear resistance for variable applications.

4. CONCLUSIONS

In this study, the wear resistance properties of Ag/SiO2/PA6 nanocomposite fabrics has been evaluated. To this end, multifilament nanocomposite yarns containing 0.01, 0.02, 0.03 wt% Ag nanoparticles were prepared from mixing of nylon6 chips and masterbatch during melt spinning. Spun yarns were drawn and finally weft knitted. The prepared fabrics were abraded until reaching the tear point and wear resistance of all samples were reported. Results indicated that sample with 0.02 wt% of Ag nanoparticles has the best improvement of wear resistance in comparison with pure sample (about 217%). This can be provided by high heat conduction of nanosilver particles as compared to polymer matrix, increasing of modulus and increasing of nanocomposite crystallinity preventing fabric folding during abrasion test. Therefore, PA6 nanocomposite fabrics containing Ag/SiO2 nanoparticles can offer high wear resistance for variable applications.

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