INFLUENCE OF HOT-PRESSING TEMPERATURE ON THE FORMATION OF ARAMID PAPER

by

Li-Rong YAO *, Xiao-Juan LI, Ye-Qun JIANG, and Shan-Qing XU

School of Textile and Clothing, Nantong University, Nantong, China

Original scientific paper
https://doi.org/10.2298/TSCI151202144Y

Meta-aramid fibrid is prepared by precipitation, and aramid fibers are mixed with meta-aramid fibrid to make aramid paper by hot-pressing technology. Meta--aramid fibrid possesses an excellent binding and adhesive properties with the aramid short fibers, yielding high mechanical properties of the aramid paper. The effects of hot-pressing temperature on the mechanical property of meta-aramid paper are mainly discussed. Experimental results indicate that the mechanical property of aramid paper increases first and then decreases with the increase of hot-pressing temperature. The fundamental cause of this phenomenon is elucidated, and the aramid paper reaches its maximal mechanical property when the hot pressing temperature is 300 °C..

Key words: *meta-aramid fibrid, aramid paper, hot pressing, adhesion, mechanical property*

Introduction

Aramid paper is made of aramid fiber and aramid fibrid, in which fibrid is used for binder instead of general adhesive. The aramid paper exhibits numerous excellent properties such as high thermal property, flame resistance, exceptional dielectricity, good mechanical and electrical insulation properties. It has been widely applied to electrical insulation, aero wing, radome, honeycomb panel, *etc.* [1-6]. The fiber and fibrid are combined together by using a wet paper-making process including wet forming, followed by a high temperature hot-pressing to form a solid sheet form.

Preparation and characterization of meta-aramid paper

Meta-aramid was dissolved in dimethylacetamide (DMAc), and meta-aramid fibrids were prepared by injecting meta-aramid solution (5 wt.%) into the high-shearing coagulant ($DMAc/H_2O = 70/30$) in a tank.

The aramid fibers with different lengths were mixed with fibrid in water, and the meta-aramid fiber was about 5 mm in length, the concentration of fibrid/fiber in water was 1 wt.%. The fibrid/fiber was dispersed in water and stirred for about 10 minutes, the mixture was put into paper machine and 2 L water was added again, stirred for a while to make hand sheet, which was dried at 160 °C, then the sample was pressed at different temperatures (250, 260, 270, 280, 290, 300, and 310 °C) at 14 MPa for 2 minutes.

A scanning electron microscope (KYKY-2800B SEM, KYKY Technology Co., Ltd., China) was used to observe the morphology of the aramid paper.

* Corresponding author, e-mail: ylr8231@sina.com

The tensile properties of meta-aramid paper, approximately 0.1-0.2 mm (height) by 20 mm (width) by 50 mm (length), were evaluated by a Kawabata Evaluation System (KES-G1, Kato Tech Co., Japan) according to routine mechanical testing methods for fabric materials. The speed rate was set to 100 mm/min.

Experimental results

The surface morphology, inner morphology and cross-section of aramid paper are illustrated in fig. 1. The images demonstrate that the aramid paper has a smooth surface and the aramid fibers are random distributed in aramid paper, which has a good bonding between fibrids and fibers. The reason is that the softening process happened on fibrid under high temperature, and the softened fibrid had an excellent holding and bonding with fibers under heat pressing. The loose structure was observed in fig. 1(b), explanation was that the heat and pressure transmit from outside to inside of paper, so the thickness played an important role in heat pressing.

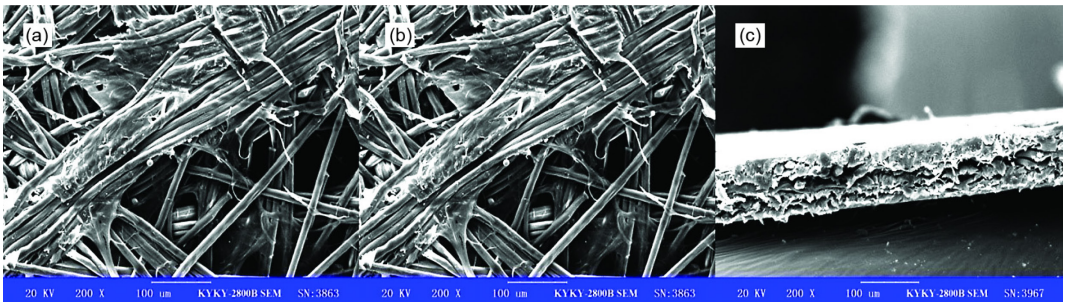

Figure 1. The morphology of aramid paper; (a) surface, (b) inner, (c) cross-section

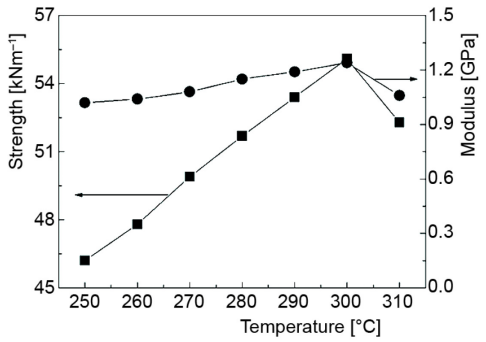

Figure 2. The relationship between temperature and mechanical property of aramid paper

The data in fig. 2 reveal that the strength and the modulus of aramid paper increase with the hot pressing temperature under 300 °C, however will decrease when beyond this temperature. The mechanical properties of aramid paper are mainly affected by the adhesion between fibrid and fibers. Under the lower temperature, the fiber is not fully softened, the bonding between the fibrid and fibers is weak, so the lower mechanical property of aramid paper is obtained. With the increase of temperature, the adhesion between the fibrid and fibers will be strengthened. However, the mechanical property of the paper will decrease when the temperature is high enough (300 °C) in that the structure of fibrid and fiber was destroyed under such high temperature.

Theoretical analysis

We consider a single fiber in the aramid paper, and assume that there are n connection points with other fibers. The strength of the fiber can be expressed as:

$$N = F + nf$$

where N is the fiber's strength in the aramid paper, n – the number of connection points, F – the fiber's strength without connection with other fibers, and f – the friction arising in connection points [7]. The friction force in our study can be expressed in the form:

$$f = \mu \exp\left[\alpha \frac{T}{T_0} - \beta\left(\frac{T}{T_0}\right)^2\right]$$

where μ, α, and β are constants, and can be determined experimentally, T_0 is a reference temperature, in this experiment we set $T_0 = 300$ °C. For our experiment, we have:

$$\frac{\alpha}{2\beta} = 1$$

A higher temperature results in a higher friction among fibers, as a result the strength of the fiber is higher. However, when the temperature reaches a threshold value, all fibers will be destroyed, and its strength becomes weaker.

Conclusion

Due to the heat and pressure transmit from outside to inside of paper, the adhesion on surface and loose structure in the inner of aramid paper were observed. It is a very essential fact that the meta-aramid fibrid has excellent binding and adhesive properties with the aramid short fiber in aramid paper. The strength and modulus increase with the hot-pressing temperature. However, the decreasing trend was observed when the hot-pressing temperature is higher than 300 °C, the melting phenomenon might happen under high temperature, which affects the binding between the fibrids and short fibers.

Acknowledgment

The work is supported by the Natural Science Foundation for Young Scholars of Jiangsu Province (BK2012234).

References

[1] Yao, L. R., *et al.,* Comparative Study on Fibrid Formation Models, *Fibers and Polymers, 14* (2013), 2, pp. 324-329
[2] Yao, M., *et al.,* Heterocyclic Aramid Nanoparticle-Assisted Graphene Exfoliation for Fabrication of Pristine Graphene-Based Composite Paper, *J. Nanopart Res., 17* (2015), 297, pp. 1-13
[3] Luo, W., *et al.*, Effect of Shape Morphology on Mechanical, Rheological and Tribological Properties of Polyoxymethylene/Aramid Composites, *Polymer Science Series A, 57* (2015), 2, pp. 209-220
[4] Zhang, J. M., *et al.,* All-Aramid Composites by Partial Dissolution, *Applied Materials & Interfaces, 2* (2010), 3, pp. 919-926
[5] Zhang, S. H., *et al.,* Comparison of F-12 Aramid Fiber with Domestic Aramid Fiber III on Surface Feature, *Applied Surface Science, 256* (2010), 7, pp. 2104-2109
[6] Zhang, S. F., *et al.,* Adhesion Force between Aramid Fiber and Aramid Fibrid by AFM, *Polymer Bulletin, 66* (2010), 3, pp. 351-363
[7] Dou, H., *et al.,* A Mathematical Model for the Blown Bubble-Spinning and Stab-of of Nanofibrous Yarn, *Thermal Science, 20* (2016), 3, pp. 813-817

Paper submitted: December 2, 2015
Paper revised: January 18, 2016
Paper accepted: December 4, 2016