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Experimental evaluation of transverse friction between fibers

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ABSTRACT

The mechanical behavior of fibrous assemblies, particularly the transverse behavior of fiber yarns and multifilament strands depends, inter alia, on the fiber-to-fiber contact and sliding. All studies on inter fiber friction presented in the literature focus on cases where the relative inter fiber motion occurs either in longitudinal-to-longitudinal or longitudinal-to-transverse direction. The transverse-to-transverse inter fiber friction plays an important role as far as the mechanical transverse behavior of fiber yarns and multifilament strands are concerned. In order to evaluate the case named here 'transverse friction, the present study proposes an original method and an associated model analyzing the transversal component of friction between two oblique crossing fibers. A relatively simple and original statistical approach has also been developed to evaluate the confidence interval of friction coefficient. The first results show a relative stability of the transverse friction. This coefficient is also significantly inferior to the longitudinal one.

1. Introduction

During the processing of fiber assemblies in a well-organized structure, either a yarn, a thin or a 3-dimensionnal fabric, the fiber characteristics play an important role in the properties of the final product. Depending on the fiber type – staple or filament one –, much research has been carried out to study the fiber length, distribution in length, fiber fineness, tensile characteristics, etc. Fiber surface properties, and especially their frictional ones, affect strongly the fiber-to-yarn or fabric transformation processes as well as the structure and mechanical properties of final products. Particularly, the yarn and/or fabric transverse compression behavior, which is a relatively important topic while numerically modeling the mechanical behavior of fibrous structures in 3-dimensionnal composite structures, depends strongly on the relative transverse fiber movement, and therefore on the inter fiber transverse friction. Despite the large number of fiber-to-fiber friction measuring devices, they focus on two main fiber configurations: violin string/bow configuration, which is often called orthogonal; and longitudinal-to-longitudinal configuration. The present study focuses on the transverse friction between individual fibers and proposes an original method to evaluate it.

2. Background

The pioneer in the friction study, Leonardo da Vinci (1452–1519) [1], suggested in 1508 that during the tangential movement between two bodies in contact, the tangential friction force is proportional to the normal force, and independent of the contact area.

Amontons (1663–1705) [2] formalized this relationship by introducing the friction coefficient μ as follows:

$$F = \mu \cdot N \quad (1)$$

where F is the tangential frictional force and N is the normal force between two bodies in contact and sliding over each other.

However, Amontons' law is not rigorously observed. Generally, there is an approximately linear relationship between the friction force and the force normal to the contact area, but that relationship varied from one material to another, from the static state to the dynamic one, and also depended on the relative movement speed.

Since 1950, the shear-adhesion theory of Bowden and Tabor [3] has proposed new methods in the study of friction and cohesion. According to this theory, the frictional force F is generally related to the normal force N using the following equation:

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$$F = k \cdot N^n \quad (2)$$

where k and n are the coefficients that characterize the friction, the index n takes the type of deformation (plastic, elastic …) of the micro asperities of the two bodies in contact into account.

Let's now consider the fiber surfaces. Due to the spinning and drawing processes of man-made fibers, their surface characteristics are generally longitudinally oriented, as it can be seen from Fig. 1. It follows that fiber-

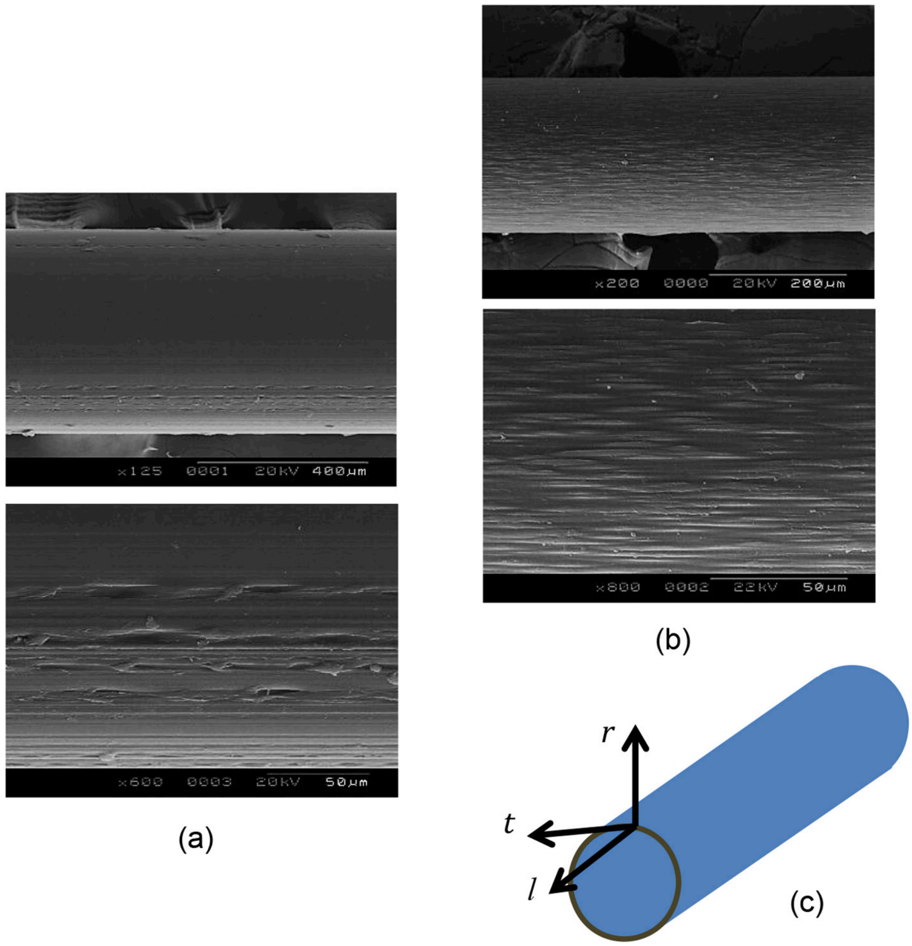

Fig. 1. SEM pictures of polyester (a) and polyamide 6-6 fibers (b), (c) fiber longitudinal - *l*, transversal - *t* and radial - *r* directions.

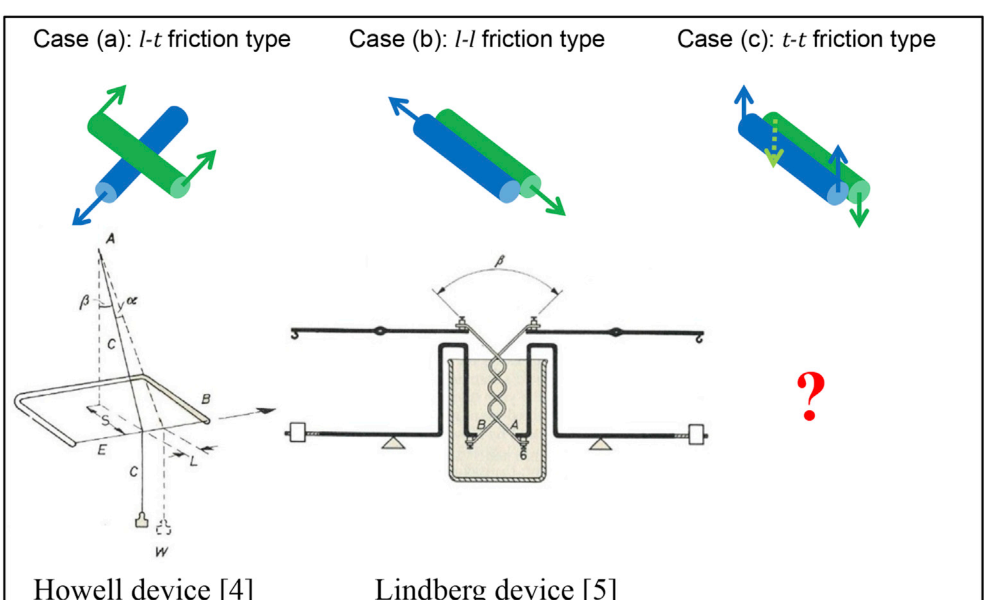

Fig. 2. Frictional measurement in different configurations, (a) Howell [4] and (b) Lindberg device [5].

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