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Experimental evaluation of oscillation model for yarn pullout test of plain-woven fabrics based on force-balance method

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In this paper, modeling of physical behavior of plain-woven fabrics under the condition of yarn pullout test is investigated. An analytical model called "the oscillation model" is represented to estimate the required force of yarn pullout test for the plain-woven fabrics. The main idea of this model is based on a combined approach of friction in interlacing points and vibration of yarns during the pullout test. This oscillatory behavior is the outcome of the stick-slip motion, caused directly by contact interactions in interlacing points. In this study, the oscillation model is investigated experimentally for five different plain-woven fabrics. The model includes many physical parameters, which cannot be measured directly. These parameters have been estimated using the force-balance model, which is another analytical model, for predicting the internal mechanical parameters of the plain-woven fabrics in the same test. Experimental results showed that the oscillation model is a suitable approach for anticipating the behavior of woven fabrics in the yarn pullout test.

Keywords: yarn pullout; plain-woven fabrics; oscillation model; force-balance model; friction

Notation

E_f	Fabric modulus in warp direction (N/mm^2)
E_y	Modulus of opposed yarn (N/tex)
E_{yf}	Modified modulus of opposed yarn (N/tex)
F	Pullout force (N)
F_S	Static friction force (N)
F_D	Dynamic friction force (N)
f	Normalized pullout force per number of crossovers (N)
F_N	Normal load acting on each crossover (N)
h	Vertical displacement of the vibrating string (mm)
K	Spring stiffness constant of the pulled yarn (N/m)
K_{eq}	Equivalent spring stiffness constant of the pulled yarn (N/m)
L	Length of rectangular sample (or string)
N	Number of crossovers in direction of the pulled yarn
t	Time (sec)
T	Propagated force through the string (N)
T_f	Lateral force in fabric length direction (N)
T_y	Force propagated in the opposed yarn direction (N)
T_{yf}	Corrected force propagated in the opposed yarn direction (N)
α	Fabric deformation angle (degree)
Δ	Displacement of fabric in the direction of pulled yarn (mm)
ΔS	Static displacement of fabric in the direction of pulled yarn (mm)
ΔD	Dynamic displacement of the fabric in the direction of the pulled yarn (mm)
ε_y	Yarn strain between two crossovers in opposed yarn direction (lateral strain)
μ	Yarn-to-yarn friction coefficient
ρ	Linear density of the opposed yarn (or string) (tex)
θ	Weave angle in the opposed direction, before pulling (degree)
$\theta\prime$	Weave angle in the opposed direction, during pulling (degree)
Subscript	
S	Parameters in maximum static situation
D	Parameters in dynamic situations

Introduction

Frictional interactions between intersecting warp and weft yarns have a great influence on the behavior of different types of fabrics, even for apparel application with deformations such as yarn running, tearing, and drape or industrial fabrics undergoing fragment impact, projectile penetration, or other large deformations. Frictional forces, which are involved in load transfer and energy absorption, directly determine the magnitude of the interactions within the fabric. Yarn-to-yarn friction as an important mechanical characteristic is measured by different methods, such as the twist friction (capstan) method, the Howell hanging fiber method, and the inclined-plane method Hong and Jayaraman (2003).

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