BACKWARD PROJECTION OF YARN AND FABRIC QUALITIES THROUGH VARIANCE TOLERANCING METHOD

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Abstract

The exact mean and variance are derived for tensile strength of a 6/1 spun yarn as a direct function of the constituent fiber length distribution, single fiber tensile properties and the "effective gauge length" *L*. The effective gauge length *L* was estimated to be 0.35 inch for the 6/1 spun yarn studied when the estimated yarn tensile strengths were compared against the actual yarn strengths. The "toleranced variances" from single fiber properties facilitate a decomposition of the total variance of the actual yarn tensile strength into three sub-components through "variance tolerancing." Effects of fiber length and strength on the resulting yarn tensile strength are examined theoretically.

Introduction

The large textile science and engineering knowledge base has not been much utilized for textile production and quality control for reasons that can be amply justified. Observing this as a failure in textile research, Suh(1) has considered some modes of failure mechanisms at work, and shown new directions for the future.

Predicting quality characteristics of textile structures from the input variables has been the targets of many research attempts in the past. The prediction equations proposed by most of these can be categorized as either statistical(2-4) or mechanistic(5-7).

The works on the basis of statistical approaches (2-4) use regression and correlation analyses in place of finding the true underlying structural relationships. The estimated coefficients thus found from specific populations and operating conditions are often highly volatile and unstable. Furthermore, proving a statistically significant relationships does not necessarily guarantee the existence of a true cause-effect relationship.

Multifactor, multi-variate models (5-7) based on deterministic, non-stochastic models have long been used to illustrate the "average" phenomena based on the input or predictor variables. Depending on the functional forms, the variances and/or the coefficients of variation (CV) of the output factors are often found to be much greater than that of the individual input factors. As the complexity of the functional form and the number of predictor variables increases, the precision of the factor to be predicted becomes extremely low. When this reality is added to the introduction of the "process variance," it is not surprising at all that the multitudes of forward prediction equations are seldom used in the quality control and improvement practice in textile manufacturing.

Most of these equations (2-7) fall under the category of forward prediction and characterization. The forward equations are both incomplete and disjoint for making true satisfactory forward prediction, while the ultimate equation, even if it is found, cannot move backward to a set of unique prior process conditions which produced the specific outcome.

Therefore, the traditional research methodology is totally ineffective in improving textile product/process qualities. The control and improvement strategies of textiles process qualities will come from a proper analysis of the process variance together with a system which can facilitate backward quality prediction and fingerprinting capabilities.

Variance Tolerancing from Fiber to Yarn

In textile manufacturing operations, the processing data often are sufficient to estimate such important variance components due to raw materials, processing conditions and time. In a spun yarn or a woven fabric, the variances of quality characteristics can be decomposed into that of sub-components under structural relationships.

Quality of a yarn is often measured and represented by its tensile strength among other characteristics as yarn breakages during spinning and weaving cause problems leading to quality and profit losses.

Let the yarn under consideration be a chain of an extended bundles of fibers which are aligned parallel to the length axis of the bundle with effective gauge length *L*, as shown in Figure 1. Discussions on bundle models can be found in the papers by Sullivan (8), M. M. Platt (9) and Pitt and Phoenix (10). According to the weakest-link theory of F. T. Peirce (11), the strength of a yarn may be modeled and estimated by the strength of the weakest bundle within a chain of bundles. In turn, the weakest bundle can be assumed to be the one which contains the smallest number of continuous fibers with an arbitrary interval size "*L*" within a yarn, when there are *r* such bundles within a test length of *rL*.

Suh (12) derived the exact distribution and moments of the number of fibers to be found within *L*, on the premise that the fiber lengths and the number of fibers found within a effective gauge length of the bundle follow certain statisti