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Image Processing and Experimental Techniques for Studying Intra-ply Shear Behavior of 3D Weft Knitted Spacer Fabrics

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Abstract

An experimental and image analysis procedure were used to study the intra-ply shear behavior of 3-dimensional weft knitted spacer fabrics. In this work, the picture frame fixture was designed to determine its suitability for measuring intra-ply shear behavior of 3D spacer fabric. The nonlinear behavior of shear force versus shear angle and the deformation mechanism were analyzed. The shear force versus shear angle curves and wrinkles position of in-plane shear test are recorded by considering two different frame lengths to compare with each other and load–displacement curves of inter-ply shear test are also analyzed. In addition to this, the program was developed in matlab using Hough transform to analyze the shear angle in the image taken during displacement of specimen at various positions. This image analyzed results were compared with the actual experimental results. The findings of intra-ply shear behavior spacer fabrics using image processing and experimental techniques are important for various functional application. From the results obtained in this work, it is suggested that the picture frame fixture still requires minor modifications to increase the accuracy of shear behavior of textile materials.

Keywords: Shear Displacement; Weft Knitted Spacer Fabrics; Shear Angle; Shear Force; Image Processing

1 Introduction

It is necessary to study the inter/intra-ply shear behavior of 3D fabric because of their wide application in production especially in the case of forming process. The in-plane shear behavior of 2D fabric has been comparatively well investigated. Zhu et al. [1] carefully investigated the in-plane shear characterization of 2D fabric by experimental test, and found that the reduction of yarn was a key to wrinkling. Hivet et al. [2] studied the shear property of 2D fabrics using picture-frame test method, and pointed out that the shear results were sensitive to the tensions in

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the yarns during the experiment. The tensile force increased with the increase in shear angle. The picture frame test is preferred by many researchers for shear testing since a near pure state of strain can be imposed within the test specimen. Shearing is induced by restraining the textile materials in a rhomboid deformation frame with fibres constrained to move parallel to the frame edges. The frame is extended at diagonally opposing corners using simple tensile testing equipment.

Lomov et al. [3] presented shear tests of unbalanced 2/2 twill glass/PP fabric on picture frame in three different pretension states and studied the influence of tensile load in the yarn direction on the shear resistance for the fabric and the repeatability of the test method. Lin et al. [4] established the finite element model based on the geometry of 2D fabric to simulate the in-plane shear deformation, the simulation results were identical with experiments. Cao et al. [5] compared the picture frame shear test results from seven different labs for developing a standard test setup and obtaining accurate and appropriate material properties. Chen et al. [6] developed a FEM model to predict in-plane and interlaminar shear properties of laminates. However, the intra-ply shear behavior of 3D fabrics was rarely reported [7]. Charmetant et al. [8] built a hyperelastic model to simulate the formability of 3D fabric.

Spacer fabrics are 3-dimensional (3D) textile structures formed of two fabric layers which are joined together and kept apart by spacer yarns. It has better mechanical and thermal characteristics compared to conventional ordinary fabric due to their wonderful 3-D sandwich structures and porous nature. [19]. Spacer fabric in which its third dimension (thickness) is significant. Components in spacer fabrics differ depending on the yarn type and production method. [9]. There are two types of spacer fabrics such as warp knitted spacer fabric and weft-knitted spacer fabric. The first type is knitted on a rib raschel machine having two needle bars [10], while the second is knitted on a double jersey circular machine having a rotatable needle cylinder and needle dial [11]. The Properties of spacer fabrics such as 3D fiber location, possibility to use different materials and production in one step, provide the spacer fabrics to use in different application areas. The major application areas are automotive textiles, medical textiles, geotextiles, protective textiles, sportswear and composites. Knitted Spacer fabrics are lightweight and breathable structures. They have good physiological and thermal comfort [12]. The increased demand of spacer fabrics and lack of comprehensive studies on the mechanical characteristics especially on shear behavior of weft knitted spacer fabrics are sound basis for this research [13].

In this research work, a picture frame shear fixture was developed and a careful study was made on its applicability in testing the intra-ply shear behavior of 3D spacer fabrics with different fabric density, thickness and structure. The shear force versus shear angle curves and position of wrinkles during in-plane shear test are recorded and analyzed. In addition to that suitable program was developed in MATLAB using Hough transform to analyze the shear angle during deformations. It can provide the foundation for investigating the performance of picture frame for intra-ply shear behavior of textile materials by both experimental and image processing techniques.

2 Materials and Methods

Six different types of spacer fabrics were developed using computerized Mayer & Cie, OVJA 1.6 E 3 WT knitting machine. These fabric samples were classified into two groups for convenient analysis of results, the first group has been developed using Polyester/Polypropylene blend with three different proportions and second group with Polyester/Polypropylene/Lycra blend having another 3 different compositions. As a spacer yarn, three different types of 88 dtex Polyester