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The Compressive Behavior of 3D Weft Knitted Spacer Fabrics Designed for Cushioning Applications⋆

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Abstract

In this research work, the effect of various construction parameters and structural characteristics of weft knitted spacer fabric on the compressive behavior and energy absorption capability was studied. The potential compression mechanism of the fabric was identified with support of the compression stress-strain curve, work done and efficiency at different compression stages. The results show that the compressive stress at the same compressive strain increases with the fabric density, and the stress-strain curves of spacer fabrics with different densities were all composed of initial, elastic region, plateau region and densification region. Third order polynomial regression model was used to establish the elastic deformation properties to obtain the compression results. The spacer fabrics ideal energy-absorption efficiency curves were obtained from their stress-strain curves and all findings show that stress corresponding to at the peak of the energy-absorption efficiency was closed to the densification stress of material. Advance statistical evaluation and one-way analysis of variance is used to analyze the significance of various factors such as thickness, spacer yarn diameter and surface structures on energy absorption at maximum compression load and deformation. These findings are important requirements for designing weft knitted spacer fabrics for cushioning applications in car seats, mattress, shoe insoles etc.

Keywords: Weft Knit Spacer Fabrics; Compression Stress; Compressive Energy Absorption; Efficiency

1 Introduction

Cushioning materials are used to dissipate the kinetic energy of the impacting mass while keeping the maximum load (or acceleration) below some limit [1]. They generally absorb kinetic mechanical energy under compression actions at a relatively constant stress over a large range of displacement. The works done by compressing these kinds of materials are equivalent to the kinetic energies of a mass that might impact on them. There are a number of materials and

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structures with the abovementioned feature for cushioning applications. Airbags, bubble films, rubberized fibre cushioning, and polymer-based foams are just a few typical examples. Foam is an important engineering material used in cushions of mattress, car seats, insole, pillows, packaging, acoustic absorption and upholstery [2]. Foams are typically used under compression, but it is very likely that also shear loading will occur in the foam components of the cushions. It is the primary means used in most modern seats, mattress and insole to achieve static comfort and vibration isolation which also happens to be the application area. It is non-linear and viscoelastic in nature. Its increasing importance as an engineering material has led to a detailed study of its structure and properties [3, 4]. The foam has a relatively complex geometry, with curved surfaces and varying thickness in order to provide the desired properties for support and cushioning.

Blair et al. [5] investigated the effect of chemical structure of Polyurethane (PU) foam on dynamic and static characteristics of the seat cushions and concluded that cushions with moderate hardness and high thickness yield lowest vibration transmissibility at low frequencies and near the resonance frequency. It has been further shown that thick PUF cushions yield lower stiffness and higher deflections [6]. However, the hysteresis loss for a thicker PUF sample was observed to be less than that of the thin foam, which led to higher vibration transmissibility.The PU foam, thanks to its specific characteristics, is the key element of the multilayer fabric in terms of comfort and mechanical behavior especially for the compression ones. The main issue with PU foam is partly the toxic gases it generates during its manufacturing process and recycling [7]. In fact, the recycling processes of such products require a delamination step of the different layers (PET, PU, PA). This operation is not optimal because some PU foam remains on the textile fabrics. It is also important to note that the machines used for the recycling are very expensive. The PU foam has many serious drawbacks such as flammability and gases emissions due to the laminating processes. These problems lead to the question of its replacement by a new product. Hence in order to overcome all these drawbacks in cushioning application, 3 dimensional spacer fabrics grab the attention of researchers in this decade.

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. [8, 9]. Spacer fabric in which its third dimension (thickness) is significant. Components in spacer fabrics differ depending on the yarn type and production method. [10]. 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 [11, 12], while the second is knitted on a double jersey circular machine having a rotatable needle cylinder and needle dial [13]. 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 [14, 15]. Their compression characteristic is also better than conventional textile structures. Compression resilience is an important attribute of spacer fabrics, which is related to sensation of mechanical comfort. Modern consumers consider compression as one of the most important attributes in the comfort sensation. Compression characteristic of knitted fabrics has been studied by various researchers [15-17]. Postle (1974) indicated that bulk density or compression property of knitted structures is related to the effective diameter of the yarn inside of the fabric and also to the fabric thickness [14]. Xu-honget. al., analyzed the stress-strain behavior of warp knitted spacer fabrics when compressed [18]. MecitArmakanet. al., investigated