WEAVEABILITY OF SPACER/DISTANCE FABRICS WITH HIGH PERFORMANCE FIBERS ON A TECHNICAL DOUBLE RAPIER JACQUARD WEAVING LOOM USING LANCETS

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ABSTRACT

In this study, a technical double rapier weaving loom was used for the weaving of spacer/distance fabrics with a polyester multifilament based ground warp, binding yarns and with polyester and basalt weft yarns. The spacing of the distance fabrics was achieved by using lancets. Four different bindings were developed and three different lancet heights have been used for the spacing. Thus developed spacer/distance fabrics showed uniform spacing between layers with a total thickness from 11.1 mm to 18.5 mm and were characterized according to their compressive resistance and energy absorption properties.

KEYWORDS

Woven spacer fabrics; Distance fabrics; Double rapier; Jacquard; Lancet.

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INTRODUCTION

Woven spacer fabrics are three dimensional textile structures consisting of two separate outer layers that are combined using binding yarns - keeping a space between two outer layers. Woven spacer fabrics are produced mainly by means of face-to-face weaving technique. Two surfaces of ground warp yarns are connected with pile yarns and for a carpet weaving, two layers are separated with a cutting mechanism within this technique [1]. Distance fabrics can also be woven using lancets. Two or more weft yarns can be inserted simultaneously into two different sheds. The distance warp yarn interlaces through the top and bottom fabric and the distance between the layers can be adjusted using appropriate lancet height. False picks or catching wefts can also be used to define the distance between layers [2]. Woven spacer fabrics can also be produced with modified double rapier weaving looms in order to weave semi-finished lightweight woven constructions [1, 3, 4]. Different geometries for the integration of foam between adjacent layers can also be realized using double rapier weaving technology with lancet systems [5]. This study summarizes the findings of the basic research for the weaveability of spacer/distance fabrics with high performance fibers using lancet systems with double rapier weaving technology, their compressive stress and energy absorption properties.

EXPERIMENTAL

Materials

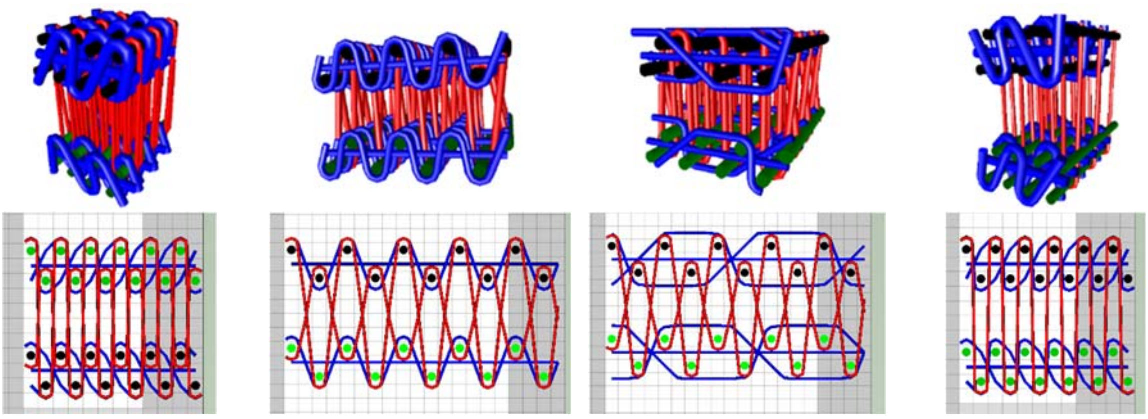
Polyester multifilament yarns (167 tex) purchased from Zwirnerei Nikol Weber GmbH were used as ground warp yarns, binding yarns and also as weft yarns. Basalt multifilament yarns (1200 tex and 2400 tex, MeltRock) were used as weft yarns for the weaving of spacer fabrics.

Methods

Four types of weave patterns were used for the study. The weave patterns were developed using the software EAT Scope Design (EAT GmbH). With this software it is possible to develop the bindings also for double rapier weaving looms. Figure 1 shows the three-dimensional models of developed weave patterns independent of yarn count and their weft cross sections. Weaves differ from each other by weave pattern within top and bottom layer and number of binding yarn group. Weave number 1, 2 and 3 have two groups of binding yarns which have the same yarn count with the ground warp yarns, whereas weave number 4 has one group of binding yarn. Weave number 1 and 4 have one-up one-down weave with a step number 1 and have reinforcement yarns between in both layers. Weave number 3 has two-up two-down weave with a step number 2 and has one-up one-down reinforcement yarns between in both layers. Weave number 2 has one-up one-down weave without stepping and also reinforcement yarns between.

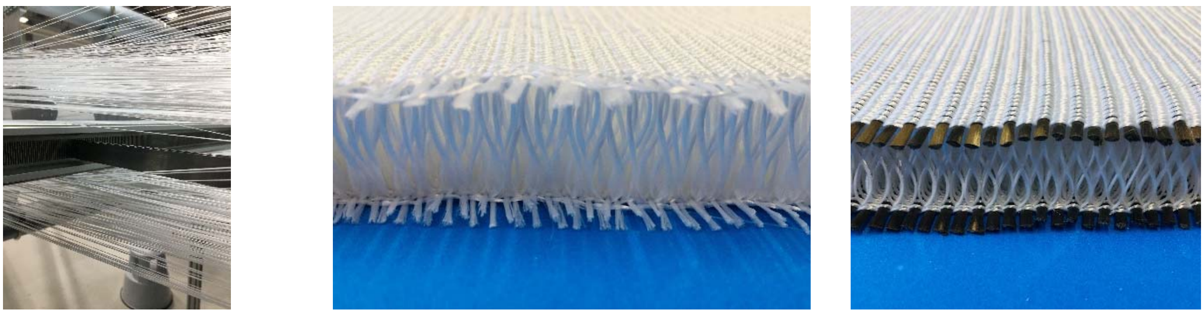
A technical double rapier weaving machine (TF 20, Stäubli GmbH, Germany) was used for the weaving of spacer/distance fabrics. This machine has a UNIVAL 100 jacquard system which makes it possible to control each harness via servo motors. Every harness can be controlled independently. It also includes special rapiers for the insertion of high performance fibers like carbon, aramid, basalt and ceramic fibers. Levelled metal lancets were used for the spacing of distance fabrics. Lancets with three different levels, respectively 10 mm, 14 mm and 18 mm were chosen for the design of experiment. For an effective shed geometry adjustment and in order to assist the weaving of outer layers, two front weaving tables were adjusted with 2 mm distance from the top and from below for every lancet height. Basalt multifilament yarns with two different yarn counts and polyester multifilament yarn were used as weft yarns whereas polyester multifilament yarn was also used as ground warp yarn and binding yarn. Machine speed was adjusted between 40 and 45 rpm during weaving. The double rapier weaving loom has a continuous and discontinuous linear take-up system. Weft densities of the woven patterns were defined during the weaving for an optimum fabric tension and these density values were noted. After each row of inserted weft yarns, distance fabrics were taken up discontinuously with a defined length. Figure 2 shows the used lancet system and the examples of woven distance fabrics.

Compressive stresses of the chosen distance fabric samples were measured according to the test method DIN-EN-ISO 3386-I. Therefore, 70 mm x 70 mm, samples were prepared and 3 samples were measured from each woven spacer fabric type. The samples were loaded 3 times up to 70% of its thickness and then unloaded, and at the fourth time loaded up to 70%. First loading cycle was taken into account for calculation of energy absorptions and efficiencies.



Weave 1 Weave 2 Weave 3 Weave 4

Figure 1: 3D models of developed weave patterns and their weft cross sections.



Lancet system Distance fabric with polyester weft yarn Distance fabric with basalt weft yarn

Figure 2: Lancet system and examples of woven distance fabrics.

RESULTS AND DISCUSSION

General findings

A uniform spacing was achieved in all of the woven distance fabrics. Weave pattern 3 with basalt weft yarn (2400 tex) could not be woven because of insufficient binding which showed up during weaving. In general, weave patterns 3 and 4 showed visually looser structures with basalt weft yarns. Adjusted discontinuous take-up distances for each inserted weft row and measured thickness values of the woven samples are summarized in Table 1. According to the results, weave pattern 2 showed less fabric thickness values than the 18 mm lancet height. This could be because of the type of binding which leads to a compact structure after the release of the woven sample from the lancet zone. Weave pattern 1 and weave pattern 2 showed sufficient binding and compact structures compared to pattern 3 and pattern 4. Generally, total fabric thickness values were up to 2 mm higher than the used lancet heights.

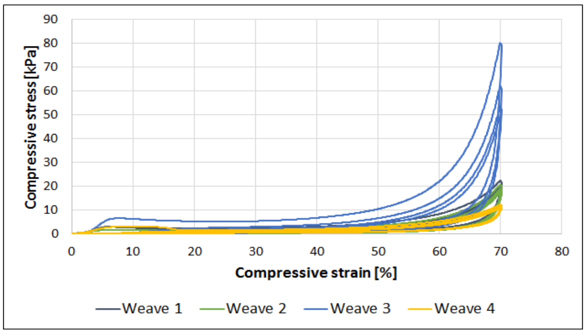
Table 1. Summary of the findings

Weave pattern	Lancet height	Take-up [mm/weft row]	Distance fabric thickness [mm]
Weave 1	18 mm	1.4 – 3.0	18.2 – 18.4
	14 mm	1.2 – 2.8	15.4 – 16.1
	10 mm	1.1 – 2.6	11.1 – 12.1
Weave 2	18 mm	1.8 – 3.4	15.2 – 16.7
	14 mm	1.4 – 3.1	15.1 – 15.4
	10 mm	1.4 – 2.8	11.5 – 12.7
Weave 3	18 mm	1.2 – 2.2	16.1 – 18.2
	14 mm	1.1 – 1.6	15.7 – 16.1
	10 mm	0.9 – 1.4	11.9 – 13.0
Weave 4	18 mm	1.2 – 3.0	17.0 – 18.5
	14 mm	1.0 – 2.8	14.6 – 15.3
	10 mm	1.0 – 2.2	11.7 – 12.4

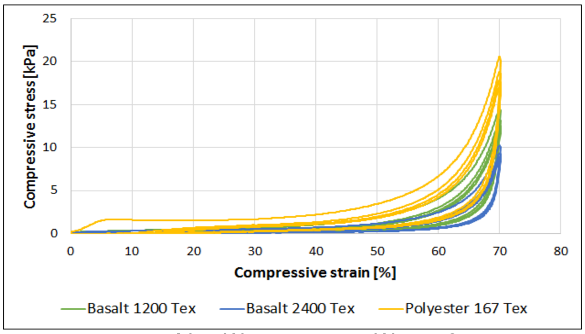
Compressive resistance properties

Compressive resistance properties of chosen woven distance fabrics were characterized according to the weave pattern, used weft yarn and lancet height. Figure 3 shows the comparison of measured compressive stress values of chosen samples.

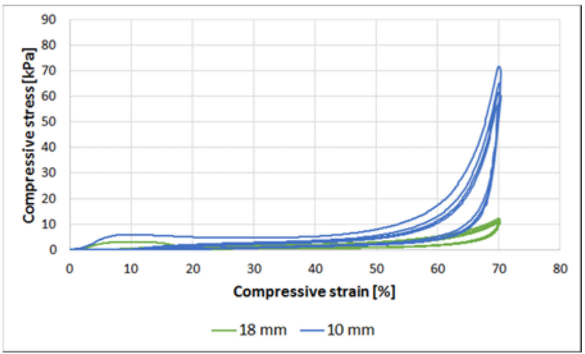
Test results show generally lower compressive stress values, because there is not a monofilament binding yarn in these structures. Binding yarns were also multifilament yarns and their yarn counts correspond to the ground warp yarns. All of the samples showed a long plateau stage, approximately up to 50 % of the total thickness. According to the results, weave pattern 3 showed the best compressive stress value when the weave patterns were compared (Figure 3(a)). Comparison of the samples with different weft yarn counts showed that the best compressive stress values were measured with the finest weft yarn; Polyester 167 tex, when the lancet height was 18 mm (Figure 3(b)). This could be due to a higher compact structure, using the finer weft yarns. Lower inner fabric thicknesses (lancet height: 10 mm, fabric thickness: 11.5 mm) showed better compressive stress values within the same weave pattern and weft yarn type (lancet height: 18 mm, fabric thickness: 18.5 mm) as shown in Figure 3(c). Weave pattern 1 with two groups of binding yarns showed better compressive stress values compared to weave pattern 4 with only one group of binding yarn as expected (Figure 3(d)). The best compressive resistance value was achieved within the weave pattern 3 with a polyester weft yarn and a fabric thickness of 11.6 mm (Lancet height: 10 mm) as shown in Figure 3(e).



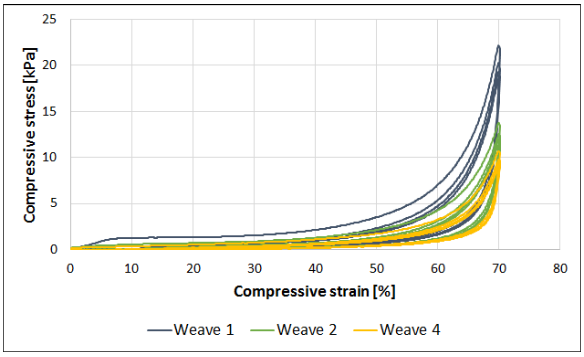
a) Weft yarn: Polyester 167 Tex
Lancet height: 18 mm



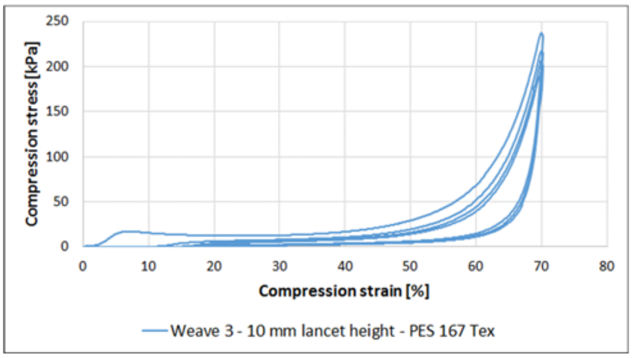
b) Weave pattern: Weave 2
Lancet height: 18 mm



c) Weave pattern: Weave 4
Weft yarn: Polyester 167 tex



d) Weft yarn: Basalt 1200 tex
Lancet height: 18 mm



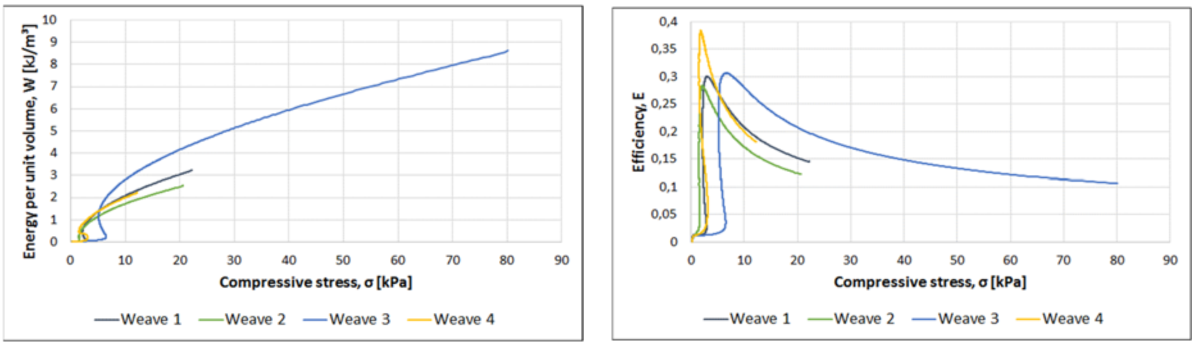
e) Weave pattern : Weave 3, Weft yarn: Polyester 167 tex, Lancet height: 10 mm

Figure 3: Comparison of compressive resistance values of chosen woven spacer fabrics.

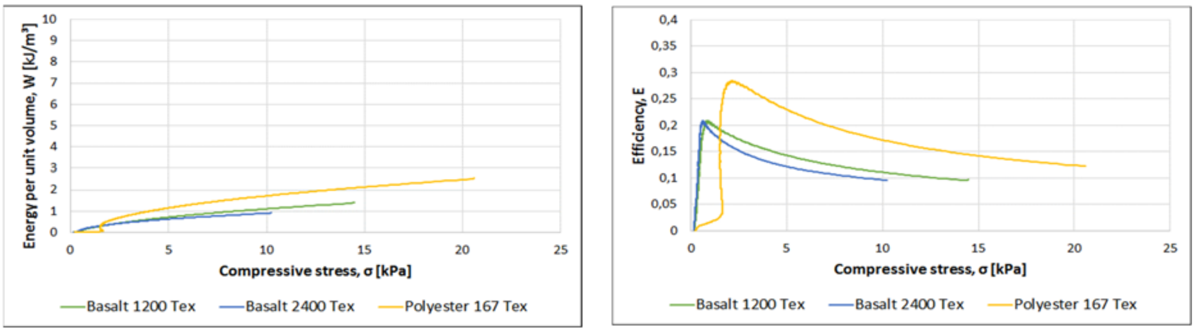
Energy absorption properties

Calculation of the energy absorbed by a spacer/distance fabric under compression has a great importance. Compressive stress – strain diagrams can also show the energy absorption behavior, but using the energy absorption diagram will clearly show the absorbed energy per unit volume in order to understand the energy absorption property of a spacer fabric in a better way [6]. An energy absorption diagram shows the absorbed energy per unit volume as a function of the compressive stress and these kinds of diagrams were used in previous studies to show the energy absorption properties of foams, honeycomb structures and spacer fabrics [6, 7, 8]. Efficiency – compressive stress diagrams were also used to see energy absorption efficiency and the plateau stress [6, 7, 8]. A dramatic increase in the absorbed energy can be seen when the stress is towards the plateau stress in the efficiency – compressive stress diagrams and the stress maintains constant. Figure 4 shows the energy absorption diagrams of chosen samples (left) and their efficiency-compressive stress diagrams (right) which are calculated from the data of the first loading cycle.

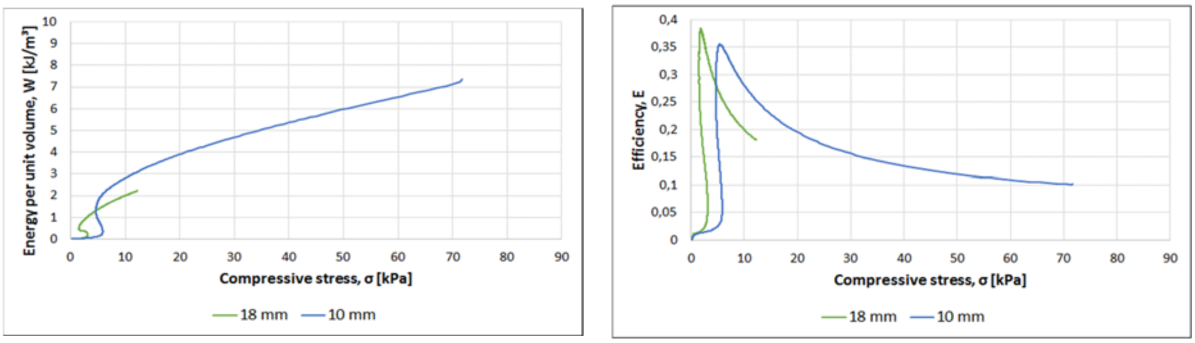
The best energy absorption property was achieved within the weave pattern 3 with a polyester weft yarn in comparison of the weave pattern (Figure 4(a)). The plateau stress of this weave was approx. 7 kPa. Up to approx. 2 kPa, weave patterns 2 and 4 showed higher energy absorption efficiencies. On the other hand, woven spacer fabric with polyester weft yarn showed a higher plague stress compared to basalt weft yarns (Figure 4(b)). Thicker woven spacer fabric showed a longer plateau zone and a lower plateau stress (Figure 4(c)). Thicker woven spacer fabric can absorb a defined amount of energy at lower stress. That means, thicker woven spacer fabric reaches its maximum efficiency point at a lower stress and energy level, which are approx. 1.71 kPa and 0.66 kJ/m³. Whereas the thinner woven spacer fabric reaches its maximum efficiency point at much higher stress and energy level, which are approx. 5.36 kPa and 1.9 kJ/m³. For this reason, both of these spacer fabrics have different working ranges. Comparison of weave pattern 1 with weave pattern 4 showed that the woven spacer fabric with two groups of binding yarns showed higher compressive stress and energy level and a higher efficiency, which is due to the effect of additional binding yarn system (Figure 4(d)). Weave pattern 3 with an 11.6 mm thickness (10 mm lancet height) and polyester weft yarn showed the highest plague stress of approx. 15 kPa and the highest energy level of approx. 4.6 kJ/m³ all among the woven spacer fabrics.



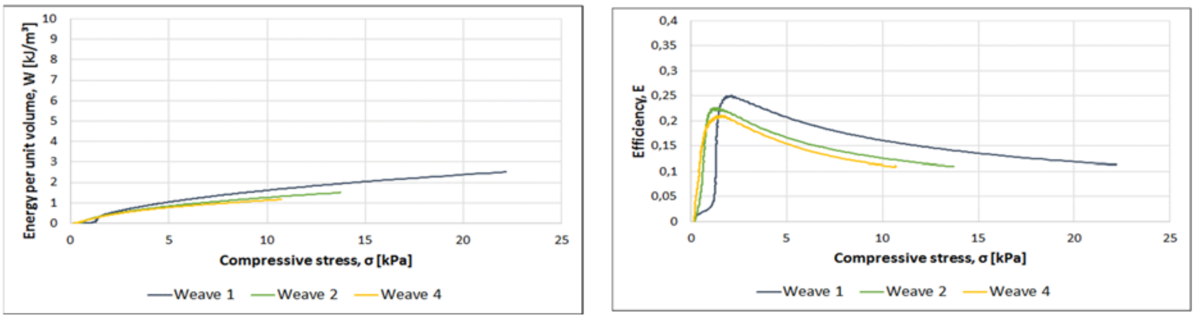
a) Weft yarn: Polyester 167 tex, Lancet height: 18 mm



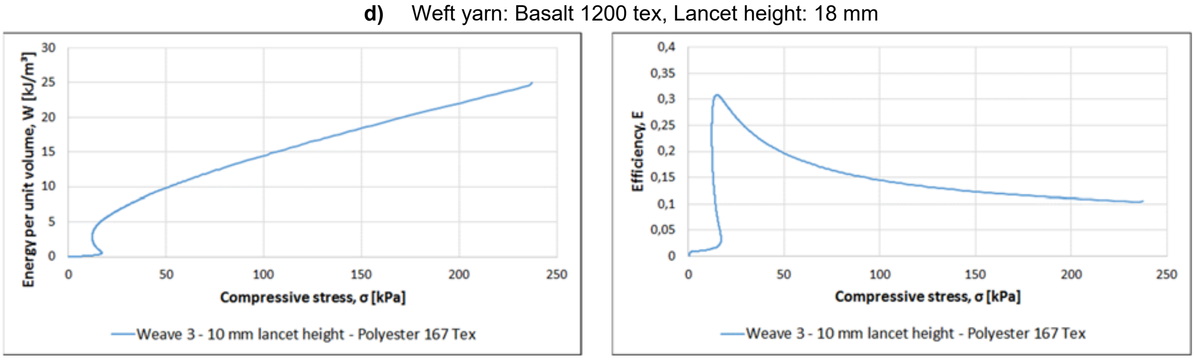
b) Weave pattern: Weave 2, Lancet height: 18 mm



c) Weave pattern: Weave 4, Weft yarn: Polyester 167 Tex



d) Weft yarn: Basalt 1200 tex, Lancet height: 18 mm



e) Weave 3, Weft yarn: Polyester 167 tex, Lancet height: 10 mm

Figure 4: Energy absorption (left) and efficiency (right) diagrams of chosen woven spacer fabrics.

CONCLUSIONS

In this study the weaveability of distance fabrics with high performance fibers like basalt yarns and polyester yarns on a technical double rapier weaving machine was discussed. Different woven fabric samples were compared according to their thicknesses and bindings. Important findings were summarized. Compressive resistance properties of chosen fabrics were compared according to their weave pattern type, weft yarn type and lancet height. Energy absorption properties of chosen samples were analyzed and compared according to the material, process and fabric parameters.

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