Usak University Journal of Material Sciences

journal homepage: http://uujms.usak.edu.tr

Research article

Application of spacer fabrics in composite production

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Abstract

Developments in the field of textile reinforced composites have been increasing in the last several years. In the first developed composite materials, fibers were used as reinforcement element. Textile materials such as staple fibers, bands, filament yarns, cables and two dimensional textiles are widely used as reinforcement elements in composite materials. Spacer fabrics consist of two outer surfaces and a connection layer between those outer surfaces. Spacer fabrics can be classified in the three dimensional textiles. Three dimensional textiles are defined as structures which have three different yarn systems (x,y,z) inside. Thanks to their special characteristics, spacer fabrics show different properties which cannot be met by the conventional textiles. Spacer fabrics can be used in different application areas thanks to their special properties such as three dimensional locations of yarns inside the spacer fabric, application of different materials in the layers and one step production property. The special characteristics of spacer fabrics present different opportunities as a reinforcement material in composite structures. There have been some researches in the literature about the application of spacer fabrics in the composite structures. However these researches are at the beginning stage. In this study, application possibilities of spacer fabrics in composites were investigated. Firstly, the physical properties of spacer fabrics were tested, then composites with spacer fabrics were produced and the properties were tested. As an alternative application, spacer fabrics were used with woven glass fabrics in the composite structure and the mechanical properties were tested. Results of the study showed that spacer fabrics present special advantages in the composite structures as a reinforcement and filler material.

Keywords: Three dimensional textiles, knitted spacer fabrics, textile reinforced composites, new composite materials.

1. Introduction

Spacer fabrics can be defined as fabrics which have two outer surfaces connected to each other with spacer yarns. Spacer yarns/layer provides three dimensional structure to the materials. Components in spacer fabrics differ depending on the yarn type and production method. [1,2,3]

Composite materials can be defined as materials which consist of two or more different materials having different properties [4]. Fibers and textile fabrics are used for reinforcement of composite materials. Fibers (staple or filament) and fiber mats are

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being used in composites for a long time. However application of textile surfaces in composite materials becomes more common in recent years [5].

Spacer fabrics are three dimensional textiles. 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. 3D weft knitted structures which is the topic of this study was used firstly in a research Project at University of Katholieke Leuven (Belgium), Department of Material Engineering. Composite production was realized with warp knitted spacer fabrics in the project [6]. Until last few years, there has not been done a detailed research about application of knitted spacer fabrics. In the literature review, some short explanations about the textile reinforced composite structures were met [7-10].

Verpoest was investigated knitted spacer fabrics as reinforcement material in composite structures [6]. Philips et al., investigated the knitted spacer fabric reinforced composite materials produced with monofilament and multifilament spacer yarns. As a result of the study it was concluded that multifilament spacer yarns provide better resin distribution although it is necessary to use monofilament spacer yarn to provide better compression resistance [11]. Philips and Verpoest, focused on the bending behavior of warp knit spacer fabric reinforced composite materials [12]. Mecit and Marmaralı studied on application of spacer fabrics in composites [13-14].

In this study, properties of spacer fabrics were investigated at first step and then composite structures were produced with these spacer fabrics and the properties were tested. In the composite production step, composites just with spacer fabrics and spacer fabrics with glass fabrics were produced. The bending strength and modulus of the materials were measured. As a result of the study it was observed that spacer fabrics provide good characteristics as filler material.

2. Material and Method

In the study spacer fabrics were produced and the properties were tested. As second step, composite production trials with spacer fabrics were realized and properties of materials were tested. In order to use spacer fabrics in composite materials as filler materials, composite materials were produced by placing spacer fabrics between two glass fabrics. Properties of those materials were tested.

2.1. Material

Multifilament yarns were used as background yarns in the structure where monofilament yarns were used as spacer yarns. Yarns used to produce spacer fabrics are shown in Table 1.

Table 1
Properties of yarns used in spacer fabric

Name	Material	Dtex	Strength (cN)	Tenacity (cN/tex)	Elongation (%)	Boiling Shrinkage (%)
Multifilament Background yarn	Polyester	111	411,4	37,07	18,36	4,5
Monofilament Spacer yarn	Polyester	111	407,2	36,69	15,24	9,2

Spacer fabrics were produced with the yarns given in Table 1. Thickness, weight, compressibility, and circular bending rigidity of the fabrics were tested. 5 tests were realized for each sample. Test results are given in Table 2.

Table 2
Average test results of spacer fabrics

Tests	Results
Thickness [mm]	3,53
Weight [g/m^2]	339,20
Compressibility [%]	33,53
Circular Bending Rigidity [cN]	5,82

Composite production was realized in two steps. In the first step composites were produced with only spacer fabrics. In the second step, composites were produced with spacer fabrics placed between two glass fabrics. Epoxy resin was used for composite production. In Table 3, properties of epoxy resin were given.

Table 3
Properties of resin used in the composites

Resin	Density (g/cm^3)	Resin –Hardener Ratio	Viscosity (mPa.s)	Hardener
Epoxy	1,15-1,17	100:32	2000	Amine based hardener

In the second step, the effect of usage of spacer fabrics as filler material in composite materials on the mechanical properties of composites were investigated and compared with conventional materials. In trials, sandwich composites were produced by placing the knitted spacer fabrics between to glass fabric layers. Properties of glass fabrics and the Coremat® filler material were given in Table 4. In Table 5, parameters for composites were given.

Table 4
Properties and materials used in the second trials

Material	Properties
Coremat®	Lantor Coremat ® XM, polyester nonwoven material, thickness: 2 mm, weight: 96g/m^2
Glass fabric	-45/+45biaxial fabric, weight: 780 g/m^2

Table 5
Parameters used in the composites

Composite Name	Reinforcement Material	Spacer fabric/ Filler material	Other materials
1K1	Spacer fabric	Spacer fabric	-
2K1	Glass fabric Spacer fabric Glass fabric	Spacer fabric	-45/+45 Glass fabric
2K2	Glass fabric Coremat(R) Glass fabric	-	-45/+45 Glass fabric+ 4 mm Coremat® (2 layers)
2K3	Glass fabric Glass fabric	-	-45/+45 Glass fabric

2.2. Method

Production of spacer fabrics were realized in a company in Turkey on Mayer Cie 3WT/2007 type cylinder-dial circular knitting machine. In Fig. 1, spacer fabric structure is shown. As can be seen in the Fig. 1, there is 3D fiber placement in the spacer fabric structure.

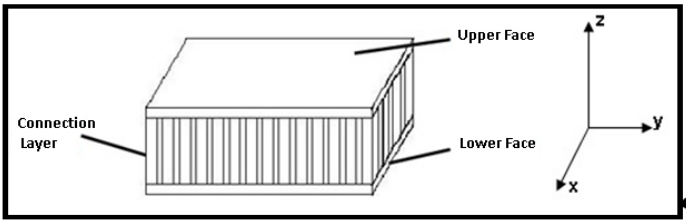

Fig. 1. Spacer fabric structure

Vacuum infusion method was used to produce composites. Firstly, spacer fabrics, Coremat ® material and glass fabrics were cut in size of 70 cm*50 cm. Cut samples were placed on the heated table which has a special coating to prevent adhesion. In the first step spacer fabric was located alone. In the second step, glass fabric layer was placed, then spacer fabric was located over and finally glass fabric was placed. In both steps, some additional fabrics were placed on the materials to make the vacuum infusion more homogenous. Composite production is shown in Fig. 2.

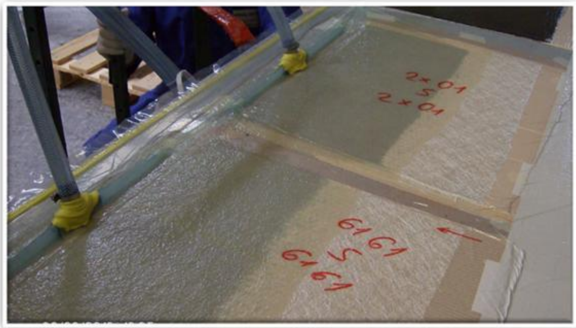

Fig. 2. Composite production

After the resin transfer completed, table was heated for curing. Curing was realized at 70° C for two hours. During curing process, some controls were done in specified time intervals. All composite materials were produced with abovementioned process.

2.3. Measurements

Thickness, fiber weight fraction, bending strength and modulus of composite materials were measured. Three point bending test were realized in order to test the bending behavior of composites according to ASTM D 790 specification on Shimadzu AUTOGRAPH AG-G Serie Universal Test Machine. Three test samples having 100 mm length and 13 mm width were prepared and tested.

Bending strength and modulus of composites produced in first step and second step were measured. Measurements were done in both length and width direction (course and wale direction). In Fig. 3, the measurement directions are given.

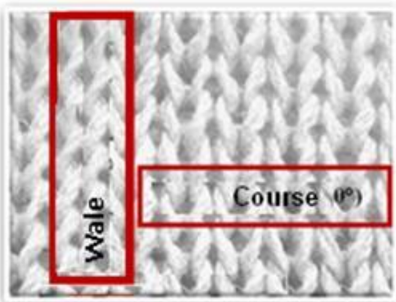

Fig. 3. Directions of composite samples

3. Results and Discussion

In the study, in order to evaluate the effect of filler material, the result of composite material which does not have a filler material (2K3), was compared with the results of composite materials having filler materials (2K1, 2K2). To compare the Coremat® and spacer fabric material as filler material, results of Coremat® filler consisting composites (2K2) was confronted with results of composite structures having spacer fabric fillers (2K1). The results of composites produced in first and second steps are given in Table 6.

Table 6
Thickness and fiber weight fraction results of composites

	Thickness [mm]	Fiber weight fraction (Wf) [%]
1K1	1.636	18.575
2K1	3.187	43.056
2K2	2.581	57.443
2K3	1.333	65.525

The thicknesses of composite structures are different. Additionally when the fiber weight fraction evaluated, it was observed that composite with only spacer fabric has the lowest ratio, while the composite with only two glass fabric layers has the highest ratio. When composites having Coremat® and spacer fabric as filler were compared, it was seen that composites having spacer fabrics has lower fiber weight fraction.

3.1 Results of Bending Strength

The bending strength results of composites produced in the study are shown in Fig. 4. Comparison of composite test results showed that usage of spacer fabrics alone in composite structures cause lower bending strength than that of other materials.

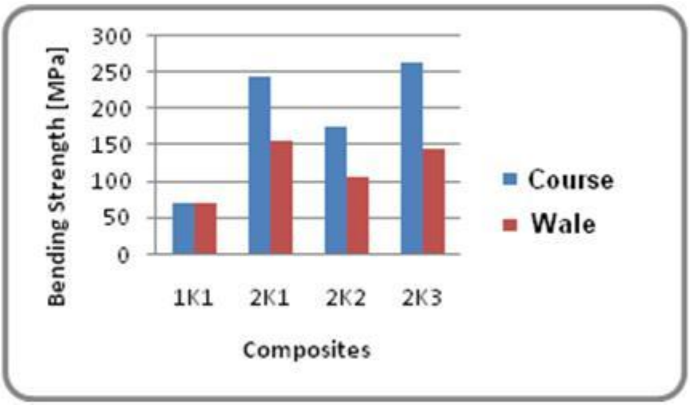

Fig. 4. Graphic of bending strength average test results

It was observed that 2K1 composite which has spacer fabric as filler material, has better bending strength than 2K2 composites both in course and wale direction. The comparison of 2K3 results with that of 2K1 and 2K2 showed that results of 2K1 are closer to results of 2K3. This result means that if spacer fabric is used in the composite structure, the bending strength of the fabric will be closer to that of composite material which does not have filler inside in both directions.

3.2 Bending Modulus Results

Average bending modulus results of composite materials are shown in Fig. 5.

The comparison of test results showed that composite material having just spacer fabric has lower bending modulus than that of other composites. As can be seen in Fig. 5, in second group, the bending modulus of composite materials in course direction are higher than that of wale directions. When results of 2K2 composites are compared, it was determined that only bending modulus of Coremat® filler containing composites in the course direction is higher than that of spacer fabric filler containing composites. However there was not observed any difference between bending modulus in wale direction.

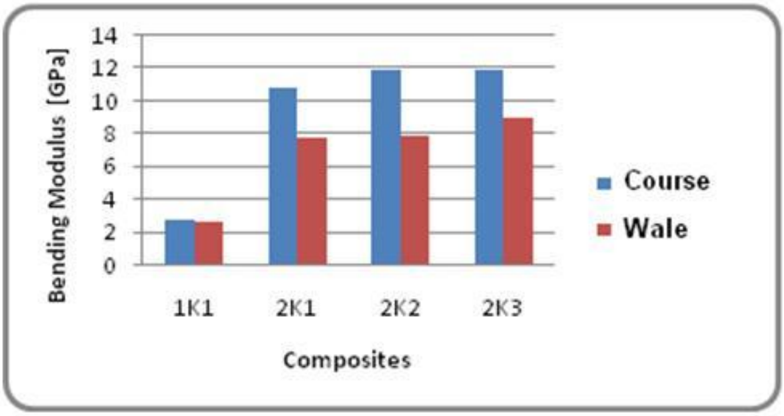

Fig. 5. Average results of bending modulus

The comparison of test results of 2K3 with 2K1 and 2K2 showed that 2K3 and 2K1 have similar test results where 2K1 has lower bending modulus results than that of 2K3 both in wale and course direction.

4. Conclusion

In this study, trials have been done in order to investigate the application possibilities of spacer fabrics in composite structures. Composites having only spacer fabrics have lower bending strength. However, spacer fabrics present different advantages as filler materials for composites. In this study, properties of spacer fabrics and Coremat® materials have been compared. Comparison of results showed that composites having spacer fabric fillers have higher bending strength than that of other material. Furthermore, bending strength of composites having spacer fabrics in both directions were very near the results of 2K3 composite which does not have filler. This result concludes that whenever the spacer fabrics are used as filler materials in composites, it provides very proximate values that of composites without filler. In the bending modulus results, there were some difference between the results of spacer fabric composite and Coremat® composite in the course direction. But the difference was not very obvious.

As a result of this study it can be concluded that, spacer fabrics can be an alternative filler material in terms of bending strength in composites.

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