Chapter 7

Textile Composites for Seat Upholstery

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Additional information is available at the end of the chapter

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Abstract

Textile for seat upholstery is a part of wide field of Mobiltech. It is very important segment of the visual identity of a vehicle, so its design, along with other high set requirements, is of the utmost importance. Textiles for seat upholstery are subject to many challenges; therefore, some of the required properties are resistance to stress, abrasion, UV radiation, external temperature and humidity, static electricity and peeling, as well as offering safety and comfort. For cladding car seat construction with textile, individual cutting parts of the fabric are joined by seam, and this part usually has the lowest mechanical properties. Therefore, in designing seat upholstery, the focus needs to be on these material segments. The function of the seam is to provide uniform transmission of loads between two joined materials and keep their integrity, which is not completely possible with stitched seam. Therefore, the material behaviour in places of sewn seam, the impact of the needlepoint and needle type on the strength, the appearance and seam quality will be discussed. Since the textile composites for seat upholstery are exposed to the multi-cyclical stress on certain areas, a part of this chapter will be focused precisely on that field.

Keywords: textiles in transportation, seat upholstery, physical-mechanical properties, biaxial cyclic stress, seam

1. Introduction: textiles in transportation

Transport vehicles imply all types of conveyance for people and cargo, such as cars, trucks, buses, trains, ships, submarines, airplanes, spacecraft and various devices for sport and recreation. The industry of transport vehicles is one of the largest users of technical textiles. Mobiltech covers all fields of transportation on land, air, space or water. The usage of Mobiltech textile is wide (**Figure 1**), where some of these materials visible (upholstery, carpets, seat belts,

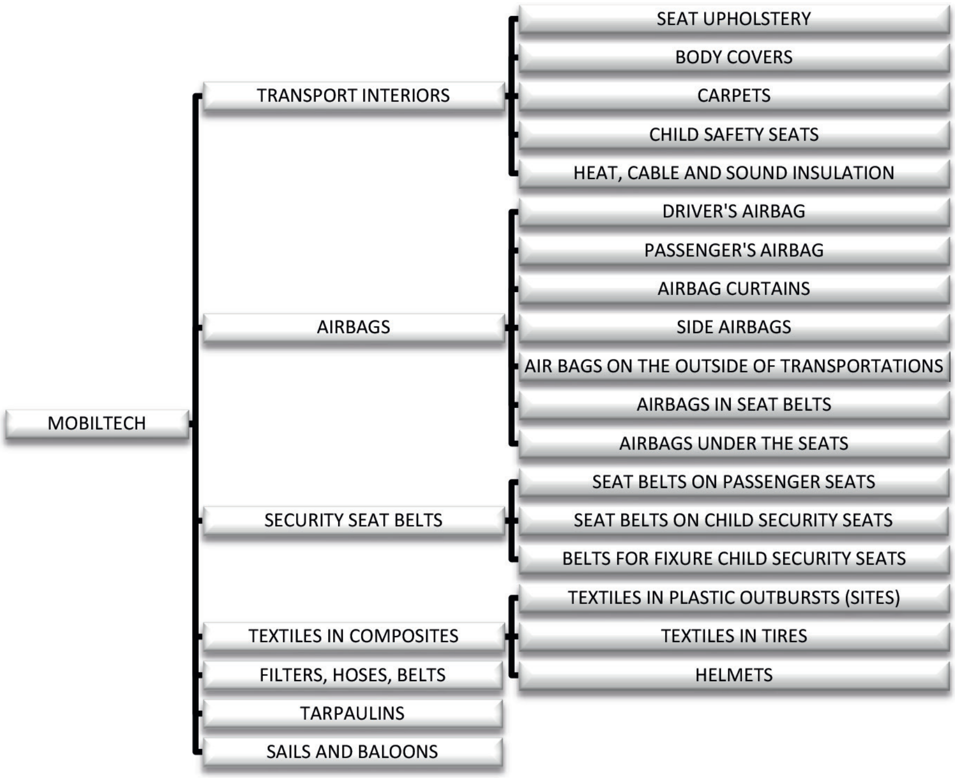

Figure 1. Distribution of technical textiles used in transport vehicles.

headliners, etc.), while other are concealed (tyre cords, airbags, hoses, belts, air and fuel filters, noise and vibration dampening, body panel reinforcement in composites, etc.).

Today's life style leads to the fact that people spend much more time in the vehicles that are sometimes used as places to work, eat, sleep, etc. Therefore, the safety and comfort of a conveyance are of paramount importance, which contributes to the design, functionality and cost-effectiveness of the vehicle interior.

Textiles in transport vehicles have multiple functions and can be summarized as follows:

- they provide a pleasant sensation during the long sitting in the same position. Textile is used for filling spaces and cladding of seat constructions (made of a metal, plastic and wood) with composite materials (woven fabric + polyurethane foam + knitting fabric) and thus contributes to its ergonomic design
- they provide passenger safety (seat belts and airbags)
- they ensure the protection of transport vehicles (shields and reinforcements for tyres, reinforcement in the walls of the transport vehicles, air and fluids filters, external airbags)
- they provide noise and vibration reduction in vehicles (multilayer materials for coating the interior).

The use of raw materials in transport vehicles is various in order to achieve the best possible application properties and maximum weight reduction (**Table 1**).

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Application area	Fibres
Upholstery	Polyester, wool, cotton, nylon, acrylic
Carpets and coverings	Nylon, polyester, polypropylene
Airbags	Nylon 6, 6, nylon 4, 6
Seat belts	HT polyester
Composites	Glass, carbon, aramid, HT polyester, HT polypropylene
Tyres	Polyester, nylon, HT rayon, steel and aramid

Table 1. Application of textile raw materials in transport vehicles.

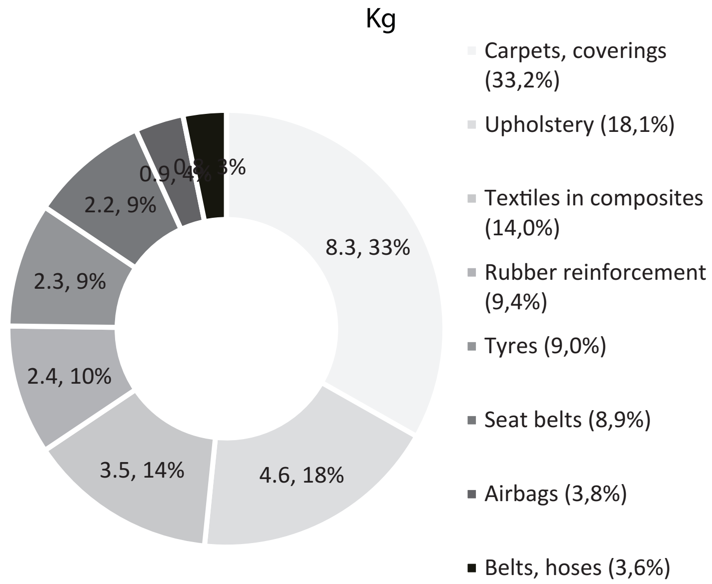

Figure 2. Textiles used in car.

Textiles in the transport vehicles, beside the basic physical-mechanical (strength, abrasion resistance, pilling) and thermo-physiological properties (comfort), must meet a number of other specific properties (resistance to sunlight and UV radiation, reduced flammability, odour free, antistatic, soil resistance) and at the same time be stable under the external temperature and humidity conditions (temperature of − 20 to + 100°C and humidity of 0–100%) through the entire vehicle life time. Textiles must also meet the high requirements for attractiveness following global trends in design.

Nevertheless, the largest consumers of textiles are still personal cars. Around 25 kg of textiles (**Figure 2**) is incorporated in the car, of which visible components cover approx. 45 m^2. In order to achieve lighter and more effective vehicle, metal parts are increasingly replaced by textile composites. It also increases the interest in the production and use of fabrics and composites made from natural fibres (cotton, flax, jute, sisal, kapok, wool, etc.) as a replacement for synthetic fibres, but these changes are still in infancy [1, 2].

2. Car seat upholstery

Almost all seats in the conveyance of passengers, that is, cars, aeroplanes and boats intended for luxury tourism are ergonomically designed with the possibility to control the height and position of the body. The shift of the seats in the vertical and horizontal direction and rotation of the backrest at desired angle enables adjustment of the best body position while driving. The gaps of the metal seat construction are filled with a variety of fibres, non-woven textiles and polyurethane foam in order to improve comfort during prolonged sitting and protect car seat cover from damage caused by direct contact with the metal frame of the seat (**Figure 3**).

The softness and breathability of the car seat upholstery material contribute to the feeling of comfort when driving, especially during a long stay in vehicle when the human body is in the passive sitting position. Long-term pressure of the same part of the body to the car seat reduces blood circulation and causes pain in muscles and joints. Functional properties and aesthetic appearance of the interior play a significant role in the vehicle selection.

The first materials used for car seats were single-layered, made from leather or rough and solid fabrics. Leather is characterized by durability, strength, abrasion resistance and appealing looks. Disadvantages of the leather seats are deformations that occur in short time of usage on sitting places and backrest as a result of long-term multidirectional stress. In the beginning of leather application, the surface of the material was not processed in order to increase resistance and protection. Therefore, additional disadvantages (of the leather material) are difficult maintenance, inadequate breathability and poor resistance to UV radiation and the impact of various weather conditions (especially in transport vehicles with unprotected seats). By its mechanical properties, woven fabric does not have the firmness of the leather, but its elastic properties ensure material stability. However, the woven fabrics have some advantages over the leather, such as a selection of various structures and designs, reasonable price, better thermal properties and softness to the touch. Today's development of textile for car seat upholstery is oriented to its structure and surface treatment. With the advent of more and more advanced textile materials and the possibility of various surface finishes, car seat upholstery is able to meet the growing stringent requirements of the market. The largest increase in the quality and functionality of car seat upholstery was followed by development of textile composite materials.

There are number of technical, design and purchase demands and end-use requirements placed on this type of materials. Exceptional strength, but also sufficient elasticity, breathability,

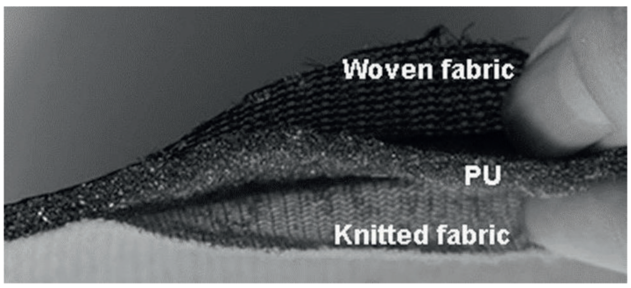

Figure 3. Composite material for car seat upholstery.

flammability and resistance to abrasion, UV radiation, extreme temperatures, humidity and microorganisms are some of the most important properties, which are achieved by using appropriate materials and structural parameters of materials and finishing process. Attractive appearance, soft touch, ergonomic design, comfort and easy maintenance will result in the feeling of pleasant stay in vehicle. Those performance properties and design are among the most important criteria for customer satisfaction. There are also some special properties, like reduction of electrostatic charge in seat upholstery (that can be achieved). A person exiting a car and leaving the seat can generate a body voltage of up to 30.000 V, which may affect passengers comfort, endanger sensitive electronic components or even cause an explosion during refuelling. Body voltage control can be achieved by interweaving antistatic yarn into woven fabric structure [3].

Targeted properties of the final composite and ultimately car seat upholstery can be easily achieved by a combination of various types of materials with predetermined properties. Car seat upholstery is exposed to multiple, long-term and cyclical stresses on the seat and backrest. Therefore, it is necessary to explore the flow of fatigue and product life by material testing with stress simulation. One of the main demands on car seat upholstery is that it should last longer than the transport vehicle. An important role in the car seat upholstery quality assessment has a sewn seam deformation. Since the sewn seam is inelastic and is usually located on the folding areas, it makes the weak point of the car seat upholstery. Prior to perform a sewing process, it is necessary to select an optimum combination of needle geometry, sewing thread, stitch class, and sewing machine type [1].

To study textile composite materials for seat upholstery, six samples with different layer thickness and lamination speed were selected. Total number of sample involves 18 composite materials made by flame lamination method with three different laminating speeds (30, 34 and 39 m/min) as a combination of woven fabric on the face of the material, polyurethane foam in the middle, and knitted fabric on the reverse. The woven fabric was produced from 100% polyester (PES) multi filament, weave: dobby, density warp/weft: 290/205 (filament/10 cm), count warp/weft: 620 f 144 dtex/167 f 48 × 3 dtex, mass 316.1 g/m^2, using weaving machine Dornier type: S 220 cm, weft insertion with rapier (electronical dobby).

The foam layer was made from polyurethane with 2 mm thickness and weight of 76.5 g/m^2 for the sample F2 and 4 mm polyurethane thickness with weight 144 g/m^2 for the sample F4 using flame lamination Schmid, model: 1281/2200.

The lower layer used as lining fabric knitted from 100% polyester multifilament, knitted fabric 1 + 1, density wales/course: 130/110 (per 10 cm), yarn fineness: 75–84 f 36 dtex, mass 51.4 g/m^2, using Terrot machine type: S296–1; E28 30''.

The results obtained by these tests are shown in the different sections of this chapter.

3. Composite material features

The first composite materials that have appeared on the market were used for making car seat upholstery, and even nowadays, they account for the largest share of the total amount of technical fabric production. In the last few decades, intensive development of materials has resulted in the emergence of new composites that meet the most stringent demands of car manufacturers. A wide range of new materials with outstanding properties and added value has been developed due to large funds investment in the car industry in order to increase market competitiveness. Developed new composites have higher level of quality and functionality. A use and qualitative value of the composite are usually determined by its physical-mechanical properties, which are directly correlated with the properties of individual components (woven fabric + polyurethane foam + knitted fabric) (**Figure 4**). Characteristics of the composites are given by the properties of the components from which the composite is made. This means that composite characteristics can be modified with combining certain properties of each component.

Woven fabric that provides the composite reinforcement is usually placed on the face of the composite material, while the polyurethane foam, in the middle, and knitting fabric, on the reverse, contribute to the composite comfort. Each component in the composite has its own function. Woven fabric with its targeted properties should provide adequate strength, aesthetics appearance, and affordable price. The second layer of the composite polyurethane foam is sandwiched between knitted and woven fabric to provide comfort when sitting. Therefore, it has to have certain elasticity, good thermal adhesion to the woven and knitted fabric in the joining process. In the same time, materials used for the production of car seat upholstery require good breathability, porosity and high elasticity. Knitted fabric used on the back of the material should protect polyurethane foam but also to improve durability, stability and elasticity of the composite material. With the implementation of new technologies, the life time of the composite has become longer. Contemporary composites have relatively higher strength, high resistance to abrasion and delamination, excellent resistance to UV radiation, good thermostability and seam quality, to achieve the best functionality and aesthetic appearance [4–6].

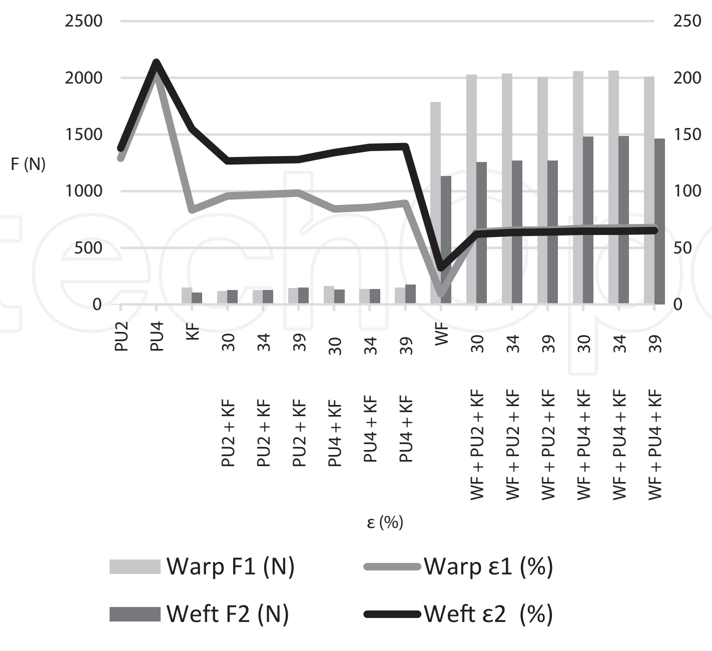

Figure 4. Tensile properties of tested materials in warp and weft direction of: each separate components in the composite (WF, PU, KF), semi-composites (PU + KF) and composites (WF + PU + KF); where WF is the woven fabric; KF is the knitted fabric; PU is the polyurethane foam (2 or 4 mm); speed of thermal joining (30, 34 or 39 m/min).

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Beside the abovementioned composite, the materials for car seats develop in the direction of production of 3D spacer textile structures. Spacer fabric is a three-dimensional network, which has two outer layer structures connected with spacer yarn, which acts as a linear spring offering more energy absorption during compression and excellent recovery at the time of deceleration. Such fabrics can be used as substitutes for polyurethane foam, which beside its specific characteristics, thanks to which is the key element of the multilayer fabric in terms of comfort and mechanical behaviour, has great number of problems. Polyurethane foam, which generates toxic gases during its manufacturing process and during laminating processes, has a problem with flammability as well as recycling issues. All these problems lead to a need for its replacement. This new product has to be environmentally friendly and has to answer to the automotive specifications in terms of weight, formability and cost [7].

4. Composite material fibre content

In the beginning of the automobile production, products for the car seat upholstery were made by single-textile materials from natural fibres (fabric) or leather. The materials had a high value of surface mass, especially in the wet state, so their durability caused problems during the usage. Former car seat upholstery had a short product life due to the following disadvantages: long water retention, slow drying, low dimensional stability in wet state and others. With the advent of synthetic fibres, natural fibres are almost abandoned from the application in the production of car seat upholstery. On exceptional basis, natural fibres such as jute, sisal and kapok, with high strength values, could be used as the alternative to polyurethane foam. Nowadays, the woven and knitted fabrics are made from multifilament, synthetic yarns in various structures, fineness and twist count.

Composites from woven and knitted fabrics made of polyester multifilament fibres are most commonly used (**Figure 5**) due to the relatively low cost and good properties. The most important features of polyester fibres are good durability and dimensional stability, high strength, easy maintenance, fast drying, low moisture adsorption, resistance to the most chemicals, resistance to high temperatures and compatibility with cotton. There are many kinds of polyester fibres on the market, of which the following is used for woven fabrics intended for car seat upholstery: FR Trevira CS: flame-resistant polyester fibres, high strength Trevira and particularly a modified polyester fibre with antimicrobial activity (Bactekiller). Rapid technological development, interdisciplinary research and cooperation between science and industry have enabled the development of new materials in composites for car seat upholstery.

Since the woven fabric is usually located on the face of the composite, good durability properties and comfort of car seat upholstery depend mostly on it. The trend of using wool-based materials for furnishing luxury vehicles is increasing. Woollen fabrics enhanced by surface treatment achieve better properties of breathability, comfort, insulation and thermal properties, compared to synthetic fabrics. Still, the woollen fabric has some disadvantages such as higher price, shorter durability, peeling tendency (in mixtures) and poor resistance to UV radiation and abrasion.

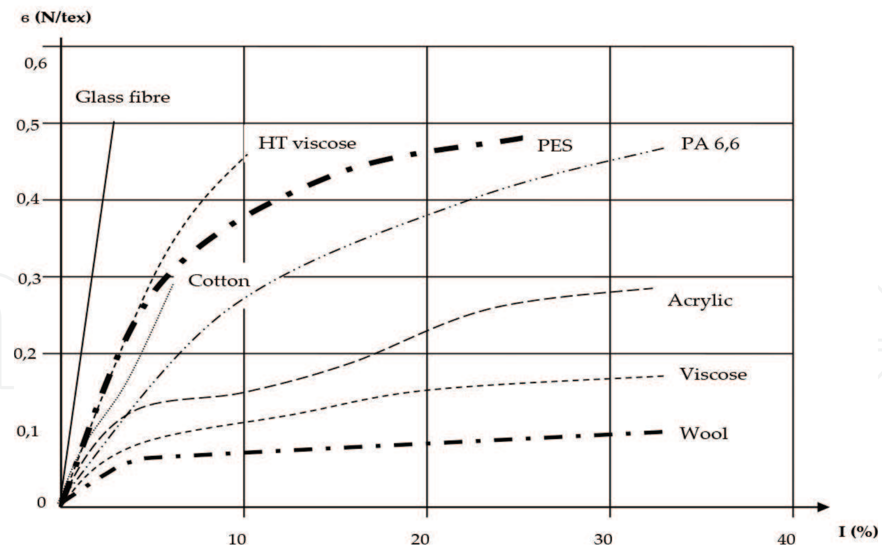


Figure 5. Tensile properties (strength and elongation) by fibre types.

Polyurethane foam has a low strength and low wear resistance but provides the car seat upholstery a very comfortable softness while sitting. One of the important properties of the polyurethane foam is its rigidity that prevents bending, wrinkling, creasing and stretching of the sitting and backrest areas during extended use. There are different thicknesses of polyurethane foams (1–11 mm) that are used in car seat upholstery composites (most often 2–5 mm). On the car seat, there are areas that are exposed to higher values of pressure. Therefore, those parts are reinforced with thicker polyurethane foam layer.

5. Thermal joining of composite

The components in the composite are thermally joined at the certain temperature and speed of the material, which has a direct impact on the final quality of the composite. Good quality of thermal joining of the components (first: PU + knitting, and then: PU and knit fabric + woven fabric) is achieved by good and solid adhesion between the components, while keeping elasticity properties.

The quality of adhesion between components can be estimated by testing the required force for composite components separation. In purpose of finding the optimal solution that will give the most solid thermal contact between the components, the separation force of composites joined with different bonding speeds (30, 34 and 39 m/min) and thicknesses of polyurethane (2 and 4 mm) was tested. The separation force between the knitted fabric and polyurethane + woven fabric composite and woven fabric and polyurethane + knitted fabric composite was conducted. Testing was performed on samples in longitudinal (warpwise) and transversal (weftwise) directions on the tensile tester Pellizzato/Tinius, C. Olsen type. H5KS, according to standard DIN EN ISO 13934–1.

Insufficient temperature in production process or an excessively high speed of the material in the process of thermal joining will result in insufficient adhesion between composite layers

(**Figures 6–9**). In addition, higher temperatures or lower velocity of the material will provide better adhesion of the components, but there is a risk that the mixture of melted adhesive agent and polyurethane foam penetrates into the structure of woven and knitted fabrics and stiffens the material. By this, the quality of material will be degraded in terms of bending characteristics and sewability.

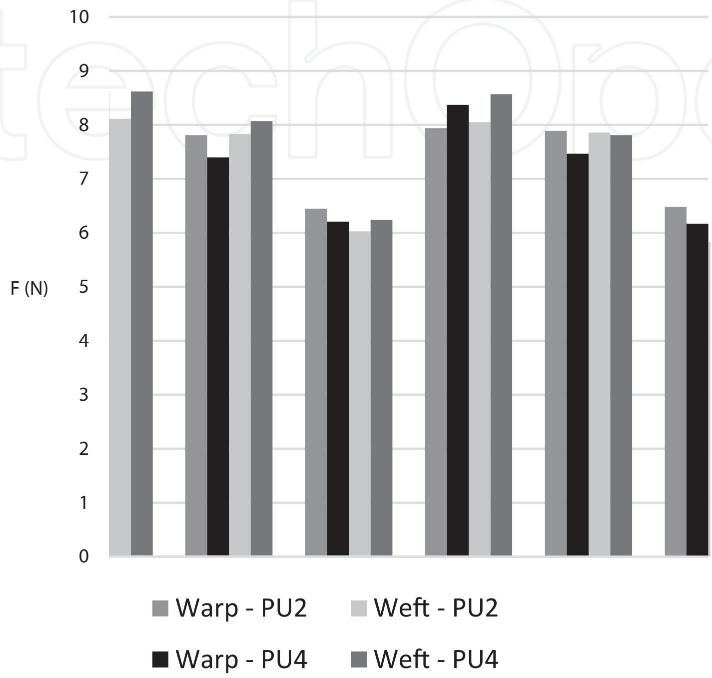


Figure 6. The separating force of the composite components, where WF is the woven fabric; KF is the knitted fabric; PU is the polyurethane foam (2 or 4 mm); speed of thermal joining (30, 34 or 39 m/min).

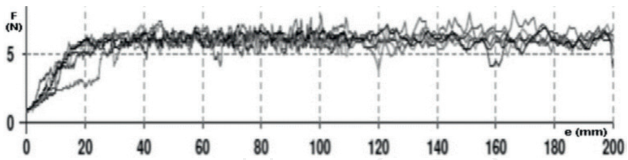
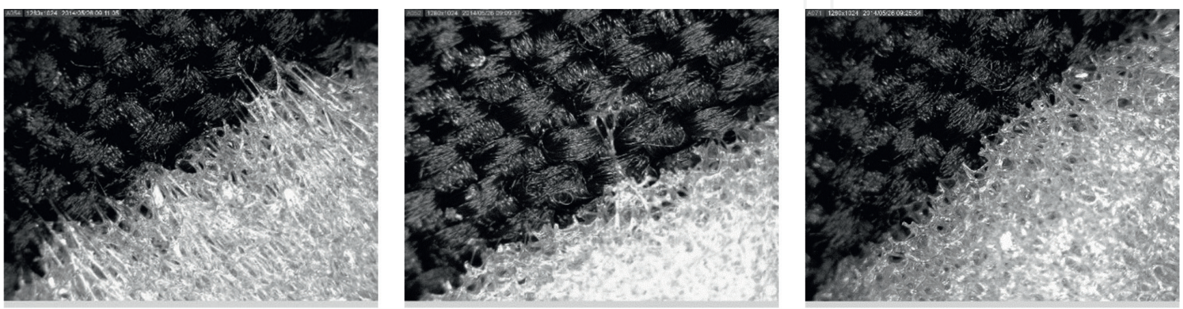


Figure 7. The movement of force and elongation at separation of the PU2 from the WF, in the warp direction, speed of thermal joining 39 m/min.



a) b) c)

Figure 8. Separation of the woven fabric from the PU: (a) speed of thermal joining 30 m/min; (b) speed of thermal joining 34 m/min; and (c) speed of thermal joining 39 m/min.

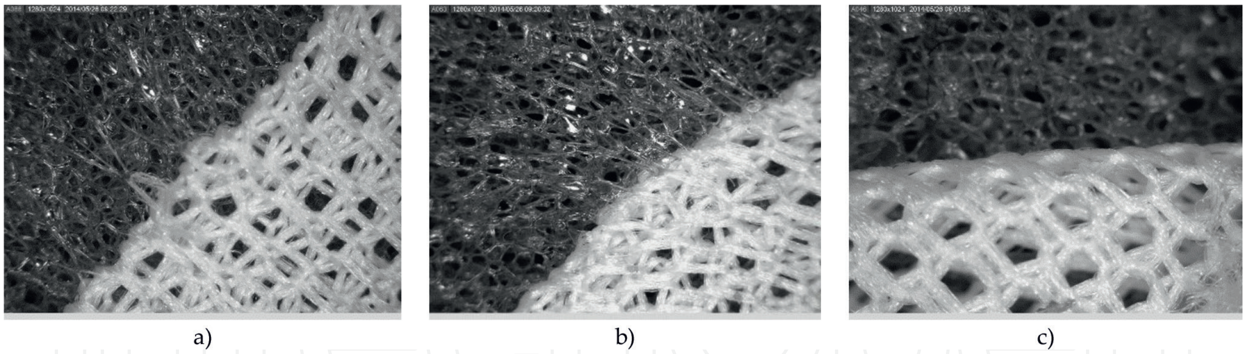


Figure 9. Separation of the knitted fabric from the PU: (a) speed of thermal joining 30 m/min; (b) speed of thermal joining 34 m/min; and (c) speed of thermal joining 39 m/min.

6. Material resistance to abrasion and determination of mass loss after abrasion

Abrasion resistance of composites, intended for car seat upholstery, is of great importance since it affects durability and quality. The test is carried out on the face of the composite, or the woven component. The tested composite (fabric) has an extremely high abrasion resistance. This claim can be supported by a relatively small loss of weight of the samples (1.2–2.5%) after 100,000 cycles of abrasion (**Figure 10**). It is important to mention the relatively big difference between the composite with a polyurethane (PU) foam thickness of 2 and 4 mm. Samples with thicker PU foam are softened, and the pressure between the fabric and the

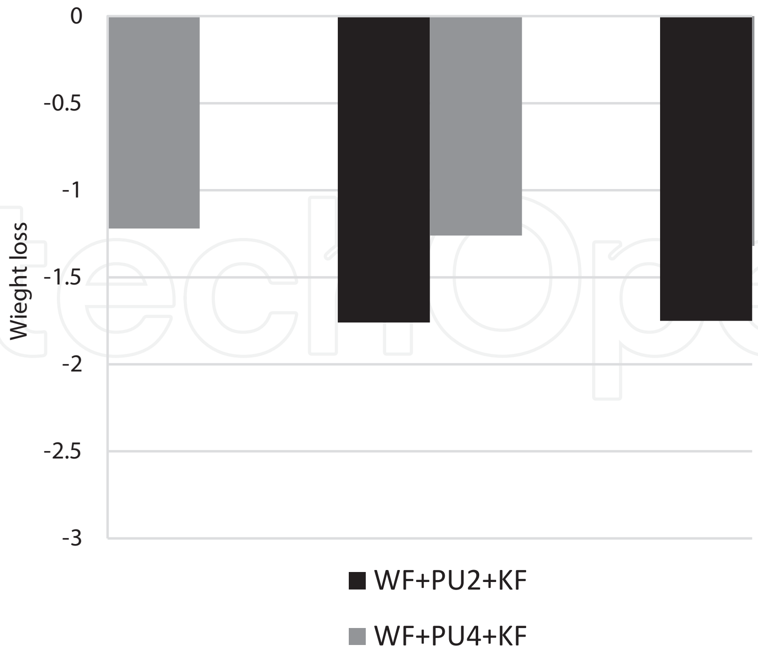


Figure 10. Mass loss of samples after 100, 000 cycles of abrasion testing, where WF is the woven fabric; KF is the knitted fabric; and PU is the polyurethane foam (2 or 4 mm).

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material, subjected to abrasion, is slightly lower, but the surface force acting during the testing also has lower values.

7. Spherical straining of material

Car seat upholstery testing of strength at a stress in the material subjected to a spherical load is of great significance. In this example, test results of various composites bursted with different diameters of the balls (60, 40, 20, 10 mm) were performed with the diameter of the ring (100 mm). The circular shaped sample with 120 mm in diameter is fixed between two rings (clamp). The sphere is placed above the sample and fixed to the movable clamp of the tensile tester. Sphere moves towards the sample at a uniform speed rate of 100 mm/min till the testing material is bursted when it stops. The results of the testing are bursting force (N) and sphere displacement (mm). The testing results on **Figure 11** show the force and the depth of sphere penetration in the moment of bursting for four different composite samples and with the four different sphere diameters. The greater penetration force is in correlation with the diameter of the sphere. Also, the higher values of bursting forces are followed by lower values of sphere penetration depth at the bursting. Considering that bursting sphere depth penetration is in correlation with bursting elongation, it can be seen that thickness of polyurethane layer has small influence in composite elastic properties in a way that thicker the polyurethane foam is, the composite is slightly stiffer. Regarding the sphere diameter, greater sphere dimensions means the greater sample area affected in testing which results in wider stress distribution ($\sigma = F/A$, where A is area which is increasing along with sphere diameter) and delayed bursting in the terms of sphere penetration depth.

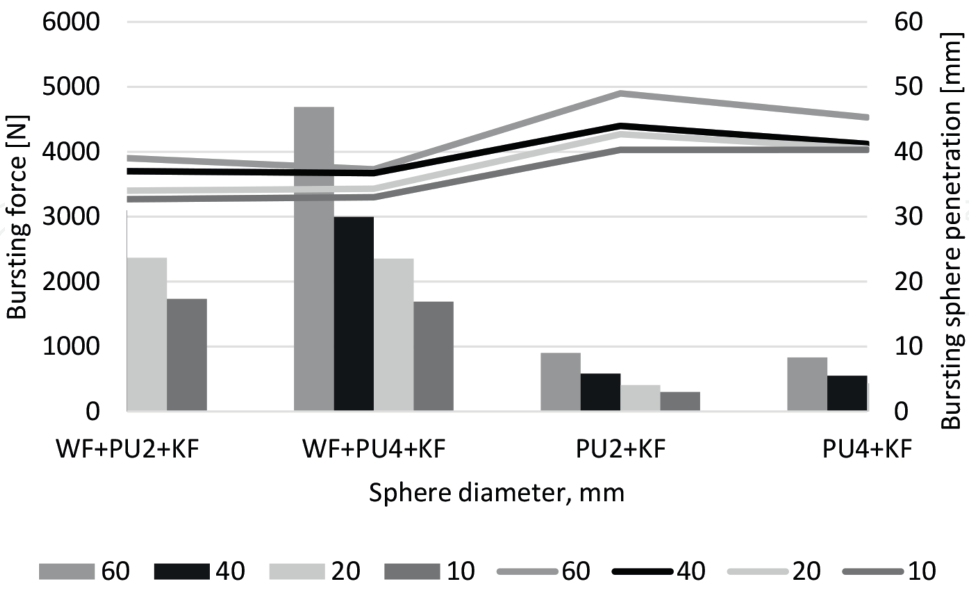

Figure 11. Bursting force and bursting depth of sphere penetration for composite samples (WF + PU + KF) and semi-composites (PU + KF), where WF is the woven fabric; KF is the knitted fabric; PU is the polyurethane foam (2 or 4 mm); and Ø is the diameter of the ball (10, 20, 40 and 60 mm).

8. Biaxial cyclic strain

A material fatigue could be determined by exposing the material to biaxial strain caused by the action of certain forces in two mutually perpendicular directions that stretch the material through defined number of cycles. It is therefore of utmost importance to define the change of rheological and usage properties of material, and its resistance to biaxial cyclic stresses. This test is particularly important on materials for car seat upholstery, in order to define their durability to multiple stresses.

8.1. The innovative device for determining material fatigue after cyclic stress

The device for measuring the resistance of fabrics to the biaxial cyclic stress is an innovative device (**Figure 12**). With this device, the material could be subjected to the cyclic stress in one or two directions. Regulation of pretension is the one of the most important actions in testing preparation, and it could be achieved with this device. Testing samples are prepared according to the method of testing (biaxial or uniaxial). The surface of the testing sample is always

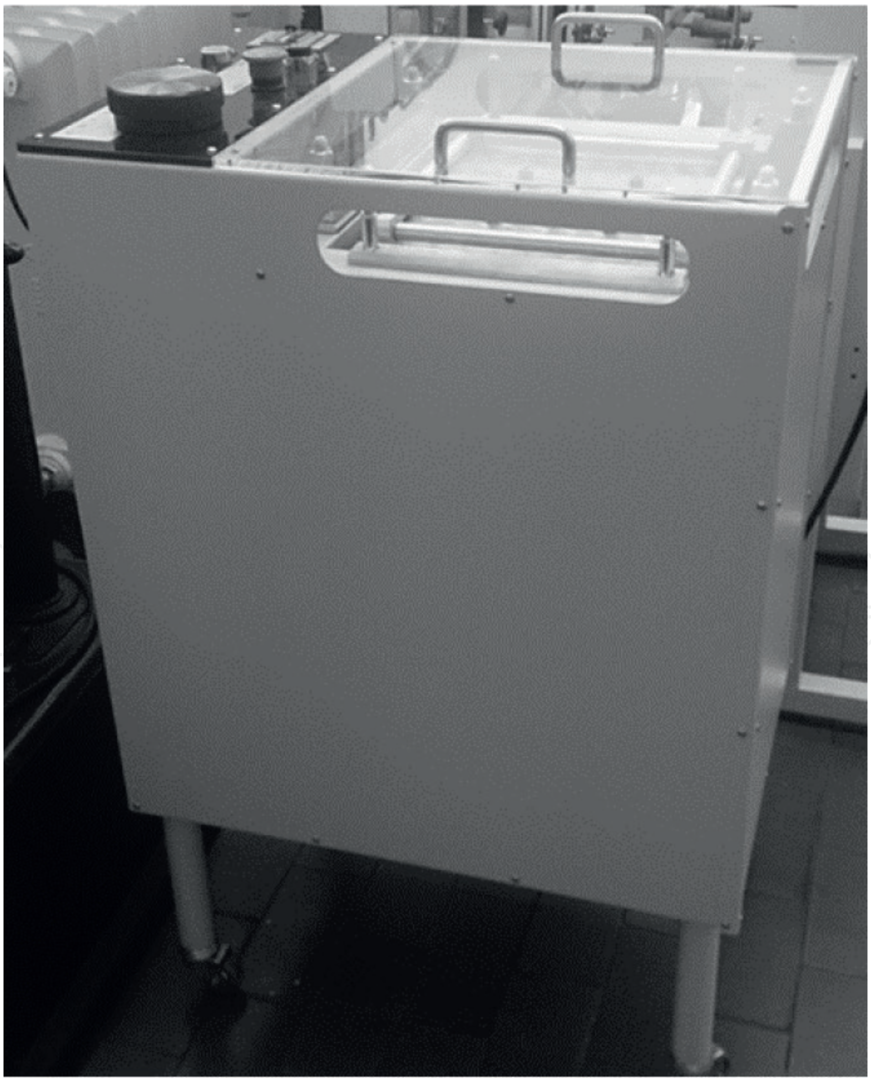

Figure 12. The device for measuring uniaxial and biaxial cyclic stress.

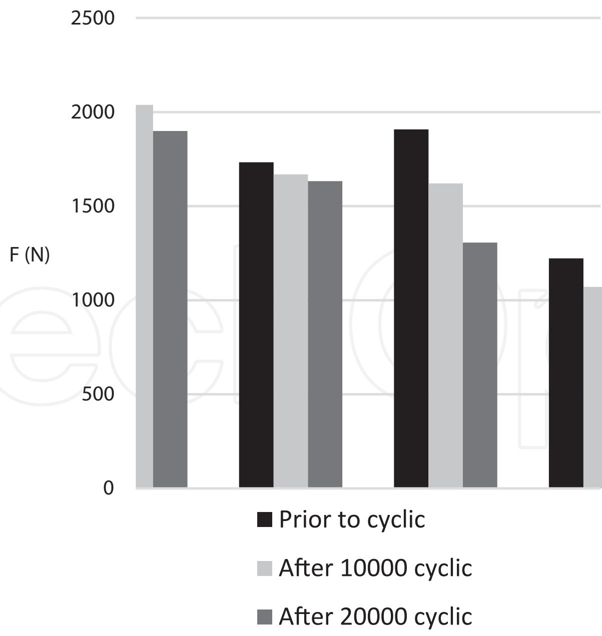

Figure 13. Breaking forces of the composite before and after exposure to the cyclic stress.

200 × 200 mm with the addition of fixing preclamps and clamps (100 mm). Sample pretension is adjusted by putting weights on two or four sides of material (depends of testing type) and fastening the preclamps to it. After a uniform prestressing, the sample is fastened by clamps that will hold it through entire testing.

The board with the side roller moves vertically in the up and down direction. At the upward move, the sample is tensed, while at the downward move, the material is relieved of stress. Cyclic strain of the sample is done by subjecting it to the certain force. The force and the speed of the board can be regulated. The device stops automatically after a specified number of cycles. The obtained samples are tested by one of the standard test methods for breaking strength and elongation of textile fabrics. The results of tests gave promising knowledge in the field of the durability of textile materials.

Figure 13 shows an example of test results for car seat upholstery materials that are cyclically burdened with a known force and then tested according to ISO 13934–1:2013 (Textiles—Tensile properties of fabrics—Part 1: Determination of maximum force and elongation at maximum force using the strip method). Due to high extensibility of individual composites components (knitted fabric, PU foam), was not possible to inflict such fatigue with cyclic stresses, by which differences in the decrease of mechanical properties could be determined. The results reveal that the material that was subjected to the action of the biaxial cyclic strain has lower values of breaking properties. A large number of cycles increase fatigue and permanent deformation.

9. The sewing of vehicle seat covers

Sewing has still a prime role in joining textiles in the automotive industry. The manufacturing of vehicle upholstery must fulfil high demands on product functionality, quality and sustainability. Sewing pattern, needles, threads and stitch density has to be carefully chosen to deliver the best possible seam quality to ensure performance standards and durability throughout the vehicle's life span [8].

Sewability is defined as the sewing thread's performance evaluated after the sewing process where the functional behaviour of the seam is described by seam properties such as seam stability (seam breaking strength and seam slippage), seam elasticity, abrasion resistance, individual product-related criteria [9, 10]. Behaviour properties of seams used for the production of vehicle seats represent the most significant problem, since the seam is the place of the weakest link in the motor vehicle seat, **Figure 14** [11].

During seam formation, the triple composite fabric is being mechanical damaged. Immediately after sewing, there are visible signs of damage on the fabric and sewing needle surface (**Figure 15**).

Needle penetration force is defined as the quantitative measure to determine the damage of sewn fabrics that has negative consequences on seam performance. The quantitative value

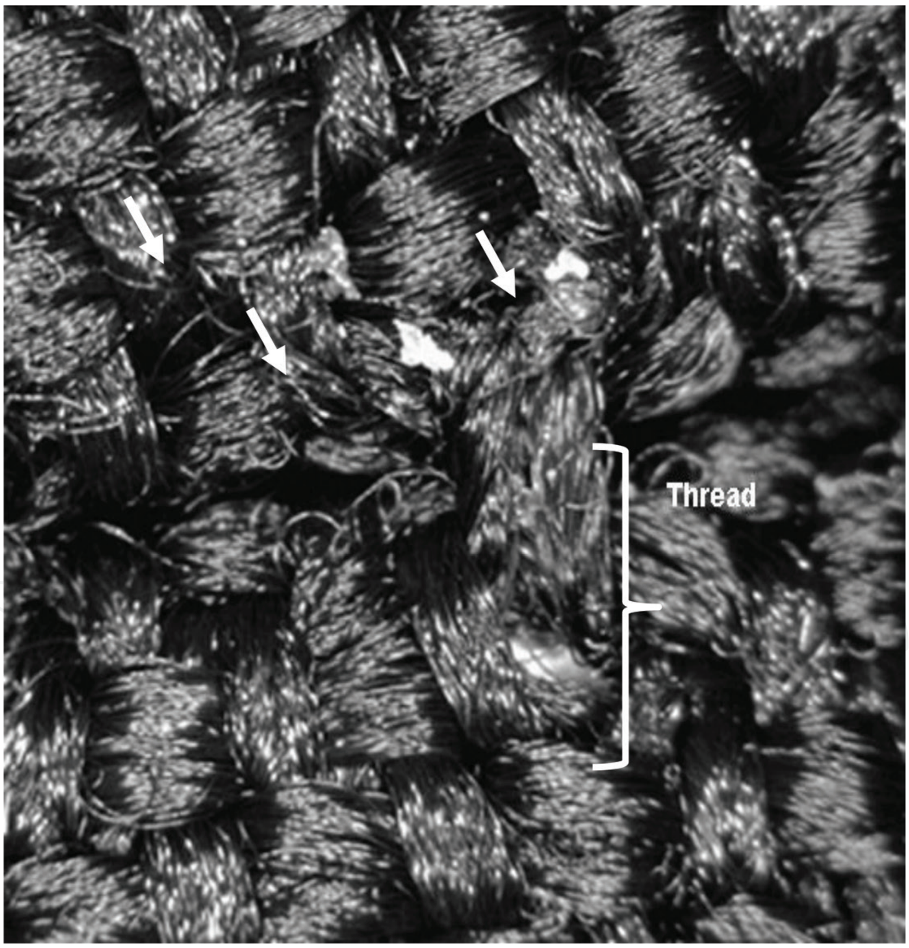

Figure 14. Mechanical damage appeared during seam formation: sewing needle penetrates through composite and drags the polyurethane foam on the front side of the composite.

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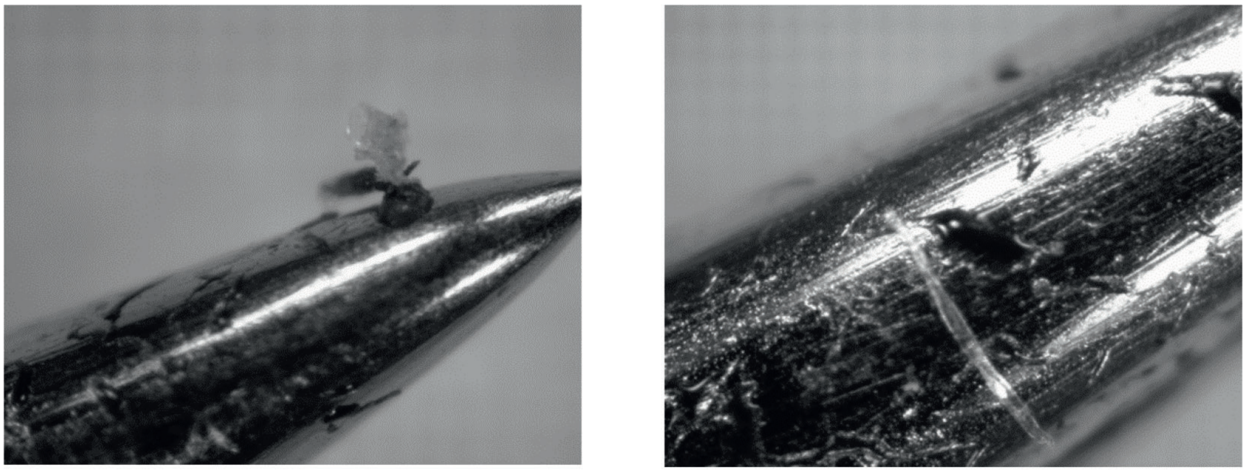
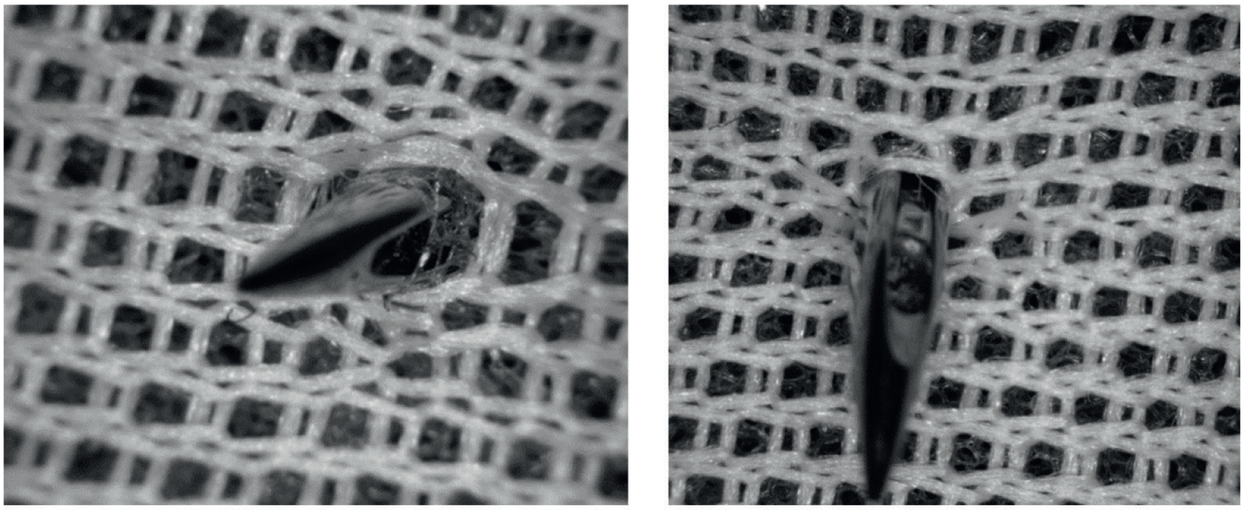


a) b)

Figure 15. Mechanical damage on needle surface: (a) sewing needle heating causes adhesion of polyurethane foam to the needle surface and (b) microscopic enlarged needle surface image with polyurethane foam.



a) b)

Figure 16. Sewing needle penetrates through composite fabric: (a) sewing needle NM 100 RG and (b) sewing needle NM 100 RG SAN6.

of force that occurs when the needle penetrates through fabric (**Figure 16**) is influenced by fabric construction, needle geometry, sewing thread construction and sewing machine settings [12–14].

If the sewn fabric has high values of needle penetration force, than there is a high risk of fabric damage because the fabric has high resistance to the penetration of sewing needle. Damage that appears after sewing process is linked to seam quality and to the quality of the final product. **Figure 17** shows needle penetration force measured on composite fabric for producing vehicle seats [13].

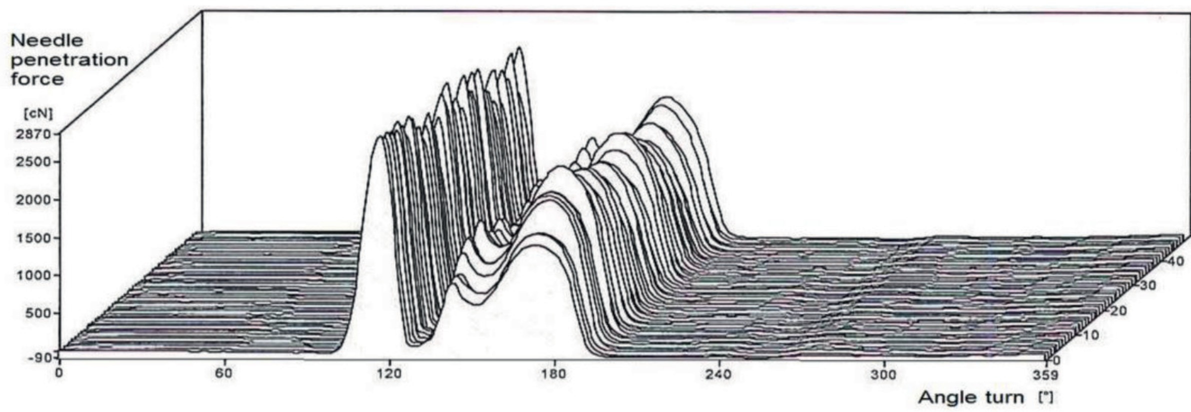
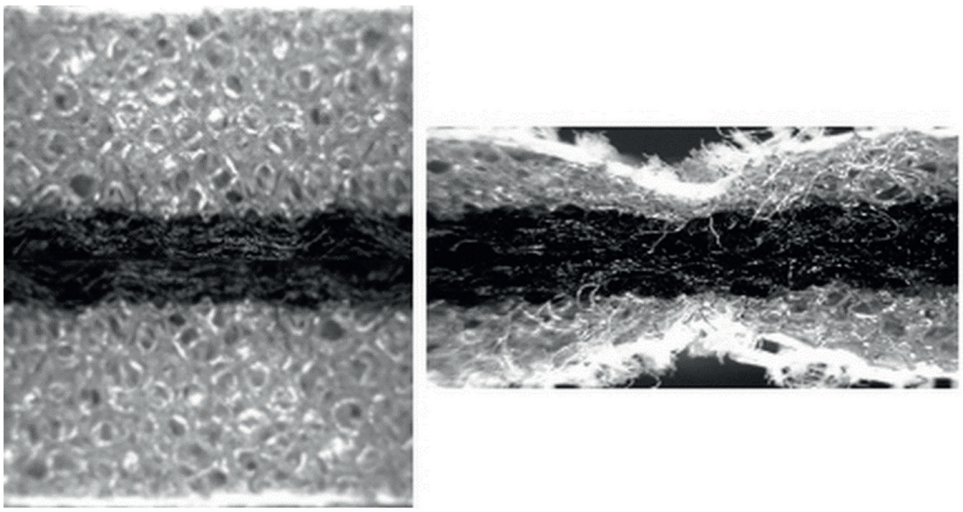


Figure 17. Graphical representation of measured needle penetration force based on 50 stitches without the use of sewing thread.



a) b)

Figure 18. Presentation of composite fabric: (a) prior seam formation and (b) after seam formation.

The function of the seam is to provide uniform load transmission of two or more connected fabric layers to achieve their integrity (**Figure 18**). At the seam position, flat composite material becomes thicker, uncomfortable in the end use, it is subjected to higher wear and forces that further weak the joint place. An additional problem in sewing ergonomically shaped seats is insufficient elasticity at the seat folding place and in the area of multi-directional stresses [6, 7, 15].

Deformation of composite fabric and sewing needle damage can be explored by a systematic analysis of the seam. Based on the result, the best possible sewing needle will be selected in the production process to achieve minimum damage to sewing needle and fabric [16–19].

The samples were sewn using 100% PES sewing thread as the upper and under thread at single needle lockstitch (ISO 4915) with stitch density of 4.5 stitches per cm. The properties of

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the sewing thread were as follows: thread finesses 97 tex, breaking force 58 N, elongation at break 18, 47% determined according to the ISO 2062 and using the Statimat M tensile tester produced by Textechno [20].

An industrial high-speed sewing machine was used to join two layers of material PFAFF 1053 in warp direction, with Groz-Beckert needles of NM 90 and NM 100, standard round point (R).

In its performance, a seam is exposed to longitudinal and transversal loadings, and thus, certain discrepancies are visible when considering breaking force and elongation at break of the seam made using needle size NM 90 and NM 100, **Figure 19**.

The seam strength was higher when using a thinner needle size for the selected material, and vice versa.

Seam quality contributes to functional and aesthetic performance of automotive upholstery in the end use. A sewn seam has a good quality if its features such as strength, elasticity, durability, security and appearance are properly balanced with the fabric properties in order to be joined together [21]. Fabrics used for the production of car seats upholstery are made as multi-layered composite materials where each fabric layer has different properties.

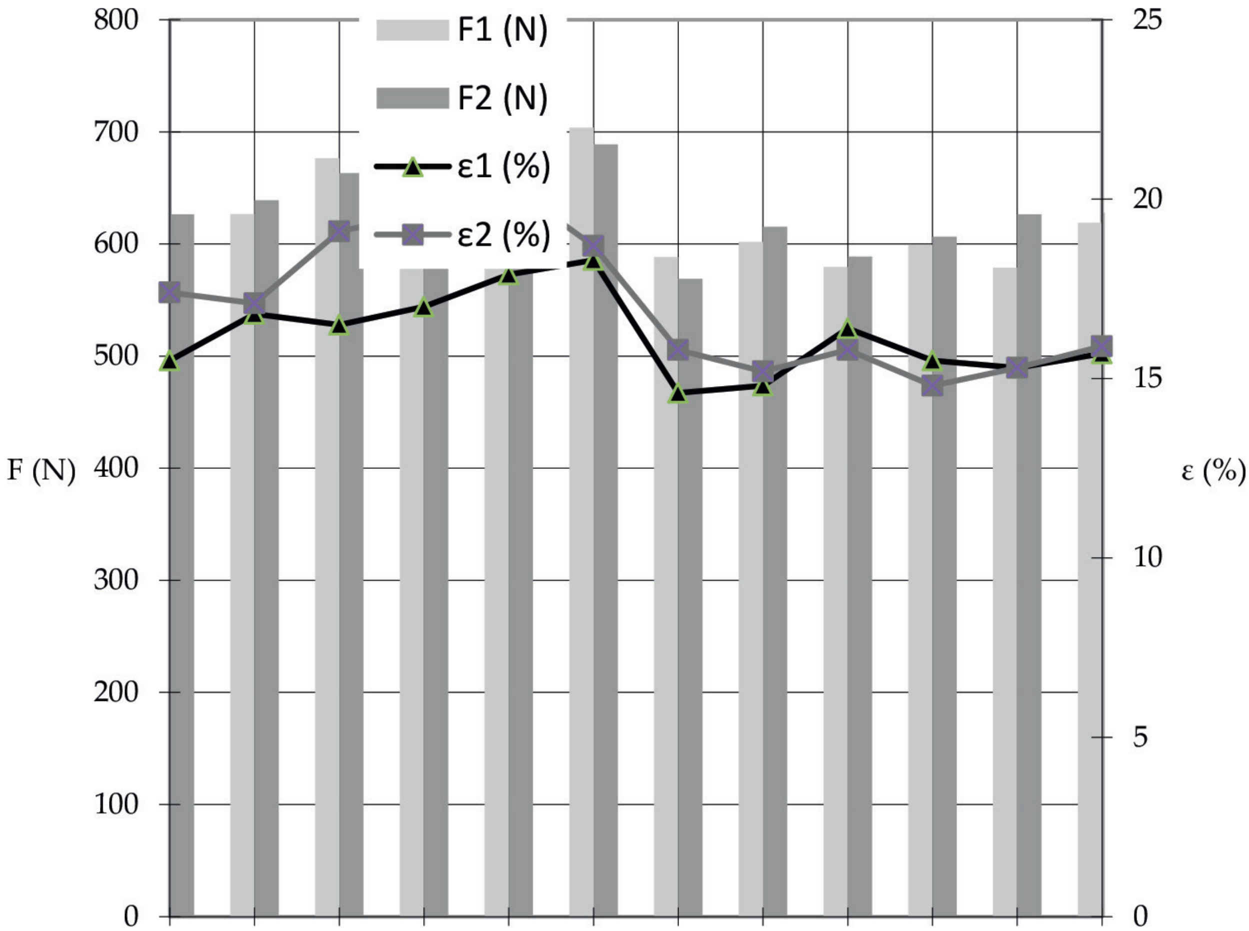

Figure 19. Breaking force and elongation at break of the seamed composite materials joined using: (a) Groz-Beckert needle of NM 90 and (b) Groz-Beckert needle of NM 100.

10. Review of the test results

The breaking strength of the composite is higher than the total amount of components breaking strengths prior to the thermal joining, at both (longitudinal and transversal) directions, at all thermal joining speeds and with both polyurethane foam thickness. Breaking forces of composites depend on the joining process speed. There is no linear trend that connects joining speed values with breaking forces of the composite. In the given example, the maximum tensile forces are at a medium speed of 34 m/min, which can be considered optimal for the tested composite.

The resistance of the composite to abrasion is essential for assessing the sustainability of the tested materials since materials in the vehicles are in the constant contact with the human body. Composite car seat upholstery is highly resistant to abrasion, where even after 100, 000 cycles, there was no appearance of the hole, and a mass loss is minimal (1–3%).

The composite with thicker polyurethane foam has a lower bursting force. This suggests that higher stiffness and thickness of the material provide less resistance to spherical stress. The greater diameter of the punching sphere is proportional to higher punching force.

Increase of the cycle number in cyclic stress setting leads to a growing material fatigue, which is reflected in the reduction of breaking force of materials tested on dynamometer.

The separation force between polyurethane foam and woven fabric is usually greater than the separation forces of polyurethane foam and knitted fabric. Lower joining process speed results in larger separation forces. Thinner polyurethane foam in the longitudinal direction results in larger separation forces, whereas thicker polyurethane foam gives higher values of separation forces in transversal direction.

The sewability of car seat upholstery is important for seam quality but also to insure cost effective production process. Good interaction of fabric properties and sewing conditions will result in good sewing performance. In a real-life situation, sewn seam is made by high-speed sewing machine where the composite is exposed to high temperatures of sewing needle and high values of needle penetration force. A seam is also exposed to longitudinal and transversal loadings, and thus, an inappropriate choice of any one element can cause failure of functional performance in the end use.

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