Analysis of Motor Vehicle Fabrics

Stana Kovačević,
Darko Ujević,
Ivana Schwarz,
Blaženka Brlobašić Šajatović,
Snježana Brnada*

University of Zagreb, Faculty of Textile Technology
Prilaz baruna Filipovića 30,
10000 Zagreb, Croatia,
e-mail: stana.kovacevic@ttf.hr,
phone: +385 1 3712575

*** Varteks d.d.,**
Zagrebačka 94,
42000 Varaždin, Croatia

Abstract
The interior design of motor vehicles depends mostly on the appearance and properties of fabric with prevailing woven articles. When upholstering motor vehicle seats and interiors, fabrics mostly constitute the exterior part of these interiors, as so-called original covers. These fabrics belong to the group of technical textiles featuring exceptionally high tenacity, elasticity, porosity and resistance to abrasion, fire and sunlight, as well as other properties necessary for this type of fabric. Airbag fabrics are of great importance because the safety of the passengers involved in an accident greatly depends on their properties and cutting forms. These fabrics should also possess certain properties such as minimal air permeability and exceptionally high tenacity achieved by the fibre raw material composition, processing procedures, fabric construction parameters and qualitatively joined places. Besides interior design and airbag fabrics, fabrics used for making seat belts are also of great importance. These fabrics are specifically manufactured on narrow fabric weaving machines. They feature high tenacity, stability achieved by a specially selected yarn and fabric construction parameters as well as by form and length, which are essential for correct bodily posture in the case of a possible accident.

Key words: *airbag fabrics, upholstery fabrics, safety belt fabrics, seat fabrics.*

Introduction

Human life cannot be imagined without woven fabric. With the good properties and comfort it offers to man, it is his faithful companion from birth up to death. Moreover, one encounters different types of fabric for different applications in everyday life.

Technical textiles in motor vehicles, where woven, knitted and non-woven fabrics are used, make up approximately 15% of the total manufactured technical textiles worldwide. More than 50% are woven fabrics because of their appropriate properties for this application [1]. Furthermore, it is possible to manufacture a target fabric that will meet all the expected requirements. These fabrics are of synthetic origin (polyester, polyamide and polypropylene fibres) with special requirements and properties. The most important properties are: tenacity, elasticity, stability, inflammability, abrasion resistance, porosity, comfort and aesthetic appearance, colour fastness in order to meet ecological requirements etc. Moreover, some necessary properties are obtained by subsequent fabric treatments such as by coating a thin synthetic layer to achieve fabric inflammability and air impermeability for airbags. To ensure comfort and safety during the journey, it is convenient that upholstery fabrics have thermal, sound and vibration insulation, which can be obtained when multi-layer polyurethane sponge and knitted fabric are used.

Division of fabrics according to their applications in motor vehicles

The use of fabrics is versatile, and they are divided into the following groups: technical textiles, clothing fabrics, fabrics for the catering industry, household fabrics, medical fabrics, industrial fabrics etc. Technical textiles are subdivided into textiles for: vehicles, civil engineering, sport, protection, packaging, furniture upholstery etc. Motor vehicle fabrics can be divided into:

- fabrics for seat upholstering and lining the vehicle interior and
- fabrics with the function of passenger safety, divided into: airbag and safety belt fabrics.

Seat upholstery fabrics for vehicles are an indispensable product, meaning that the necessary properties cannot be achieved with other products. The highest share of fabric in vehicles is upholstery fabric, approximately 85% [1, 2]. Fabrics for upholstering the vehicle interior are mostly of synthetic origin, but it is recommended that covers used for making original covers should be of natural raw materials, which provide a comfortable feeling to the touch. They do not have anti-allergic characteristics, produce no static electricity and pilling, are airy and comfortable, and have very good physical-mechanical characteristics etc. Airbags and safety belts belong to passenger safety fabrics. This group of fabrics has a considerably lower share in motor vehicles in relation to upholstery fabrics, amounting to approximately 9% for airbags and approximately 4% for safety belts [3]. The first driver airbag was built into a car in 1980, although it had already been pat-

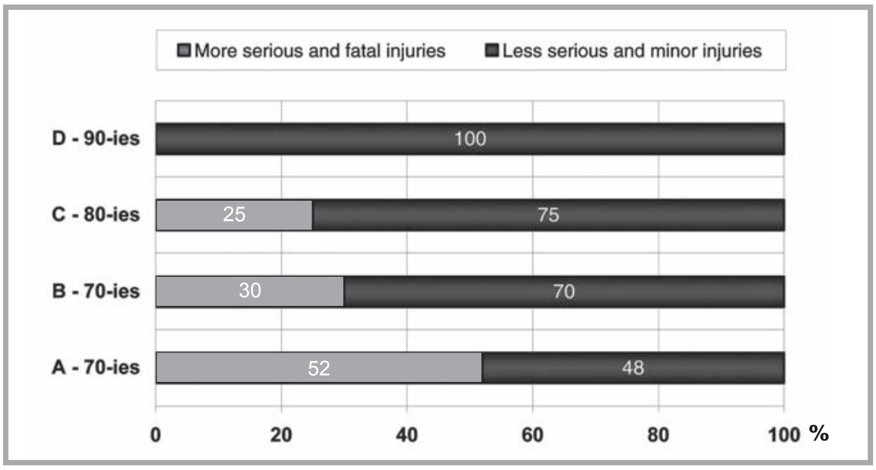

Figure 1. *The impact of safety belts and airbags on the injuries of traffic participants in a car accident: A – no safety belt in the 1970s, B – with safety belt in the 1970s, C – with safety belt in the 1980s, airbag, safety belt tensioner and improved collision structure, D – with safety belt, adaptable airbag, belt tensioner and belt end stop, and more improved collision structure in the 1990s.*

ented at the beginning of the 1950s. The first co-driver airbag was introduced in 1988, side airbag in 1995 and air curtains in 1998. Accurately timed activation of the airbag requires the system developed in 2002. Continuous development is improving it more and more (***Figure 2***). By developing the car over the last 25 years, airbags were changed and adapted to the car shape and speed [4-8]. ***Figure 1*** [4, 9] displays the injury analysis with and without airbags and safety belts.

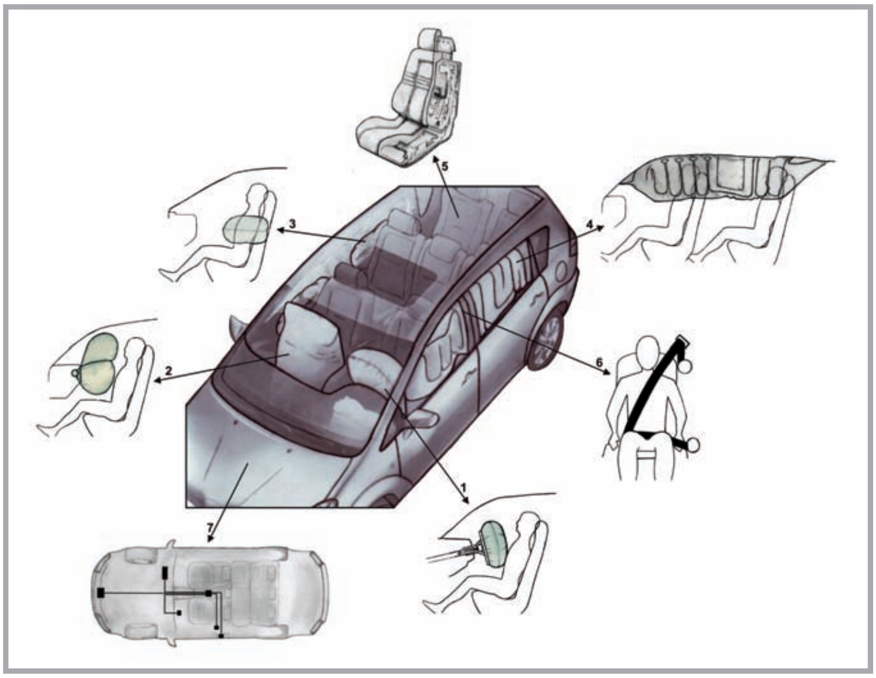

Figure 2. *Automotive fabrics: 1. driver airbag fabric, 2. co-driver airbag fabric, 3. side airbag fabric, 4. curtain airbag fabric, 5. seat fabric, 6. safety belt fabric, 7. airbag sensors.*

In each new car, there are at least two front airbags built in for the driver and co-driver (***Figure 2***). The average number of airbags per car increases constantly and has almost reached a two-digit number. Contemporary airbag systems measure the passenger mass; they are activated through several "phases" or are not activated if there is no passenger in the seat or if the passenger is not buckled up [10].

Airbags are built into back seats for greater passenger safety. Likewise, so-called curtain airbags are built into side car parts to alleviate passenger impacts against the side glass and to protect the passengers during car overturning. The curtain airbags cover the whole top part of the car side. It is important that the airbags are inflated in due time, in about 25 milliseconds. This seat airbag is made of a 0.3 mm thick metal foil and looks like an envelope. It is the only airbag not made from fabric. By furnishing the car with seat airbags, a higher effectiveness of the frontal airbags and curtain airbags is achieved during car overturning because the body remains in the right position [11]. The seat airbags and safety belts disable forward body movement at the moment of a crash, fixing the body in the seat. It is of paramount importance to join the cutting parts of the airbag properly. They can be woven partially or completely seamlessly. The cutting parts can be joined by sewing (***Figure 3***) or thermal joining. Nevertheless, airbags are mostly sewn for the reasons of safety and achieving proper seam strength and stability. An incorrect stitch length or skipped seam could be fatal in the case of a car crash. The sewing machine should be able to sew two or more layers of a dense woven fabric without damaging the sewing thread, requiring a great robustness of the machine and the use of special sewing needles [12]. In the case of a frontal collision, the gas generator (explosive) inflates the airbag, which lifts the front part of the seat. The airbag volume is approximately 5 l, and it is inflated all the time owing to the valve controlling air escape.

The Schmetz Company (Germany) developed a special Schmetz serv 7 needle that prevents deflecting when sewing multilayer fabrics and does not damage the material owing to its thickened needle blade (***Figure 3***) [13, 14]. Its special form contributes to avoiding defective stitches and needle breaks. The sewing thread is "bonded", meaning that the components of the thread are glued, and the thread cannot be "opened" in multidirectional sewing and relatively high abrasion. The thread is mostly manufactured from polyamide 4.7, having greater warmth conductivity (melting point at 285 °C) than other polyamide types (melting point at 235 °C) or e.g. incombustible aramid thread (melting point at 370 °C) [13].

Safety belts also play a significant role in terms of passenger safety in motor vehicles [15, 16]. It is important to fasten safety belts properly because they significantly reduce passenger injuries in the case of a car crash. A safety belt's tight contact with the body at several points secures the position of the passenger and disables him from sliding from the seat and hurting the body during the crash and possi-

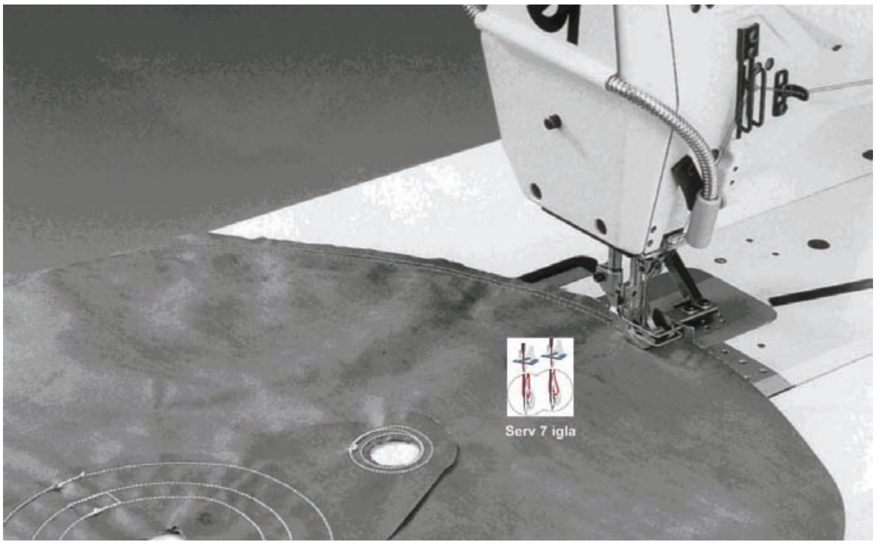

Figure 3. *Sewing of airbag, tt. Durkopp Adler.*

Table 1. Basic fabric parameters.

Parameters tested and standards		Airbag fabrics				Upholstery fabrics				Safety belt fabrics			
		Sample I	Sample II	Sample III	Sample IV	Sample V	Sample VI	Sample VII	Sample VIII	Sample IX	Sample X	Sample XI	Sample XII
Fabric density, threads/10 cm ISO 7211 (HRN F.S2.013)	Warp	180	211	205	200	135	150	340	240	625	585	650	700
	Weft	180	188	155	145	120	115	220	190	140	140	150	140
Yarn count, tex ISO 2060 (HRN F.S2.012)	Warp	50				50	50	67	66	180	190	180	180
	Weft	50				59	60	67	73	90	65	70	70
Raw material composition	Warp	Polyamide 6.6				Polyester				Polypropylene			
	Weft												
	Lining					Sponge: expanded, polyurethane							
						Knit fabric: polyacril							
Mass per unit area, g/m² ISO 3801 (HRN F.S2.016)		228.8	291.6	268.0	249.9	291.5	311.7	402.4	358.7	1307	1240	1333	1375
Fabric thickness, mm ISO 5084 (HRN F.S2.021)		0.27	0.31	0.31	0.29	1.10	1.19	1.34	1.25	1.24	1.19	1.28	1.28
Weave		Plain weave				Jacquard structures				Broken twills			

ble car overturning. Besides, keeping the body in its proper sitting position enables the effectiveness of the airbag; otherwise, it may lead to a counter effect. This is to say that the airbag, if the body is not in the correct position, will not compensate for the impact of the head and the vehicle part, but may push the body of the passenger away and cause more serious injuries. Safety belts are manufactured by narrow weaving, and the following properties are required: high tenacity, stability, the raw material composition is mostly polyester multifilament, a relatively high density of warp yarns and a relatively low density of weft yarns, twill weave is used in the weaving etc. Certain durability, uniform tape thickness and width are required in order to ensure faultless application for the whole lifetime of the car.

Table 2. Breaking force and elongation at break of the yarn with statistical data.

Yarn parameters			F, cN	S, cN	CV, %	I, %	S, cN	CV, %
Sample I	Airbag fabrics	Warp	1790.0	53.7	3.0	21.0	1.0	4.7
		Weft	1618.4	71.2	4.4	23.5	1.2	5.1
Sample II		Warp	1609.3	54.7	3.4	20.2	0.8	4.2
		Weft	1325.5	66.3	5.0	22.3	1.0	4.5
Sample III		Warp	1810.0	74.2	4.1	19.7	0.8	4.0
		Weft	1603.7	75.4	4.7	23.3	1.1	4.8
Sample IV		Warp	1887.5	68.0	3.6	21.0	1.0	4.7
		Weft	1821.7	98.4	5.4	23.5	1.1	4.7
Sample V	Upholstery fabrics	Warp	1320.0	96.4	7.3	25.7	2.7	10.7
		Weft	1310.2	140.2	10.7	27.0	3.1	11.5
Sample VI		Warp	1351.5	120.3	8.9	26.8	3.45	12.9
		Weft	1300.8	127.5	9.8	26.2	3.1	11.9
Sample VII		Warp	1418.7	141.9	10.0	27.4	3.2	11.8
		Weft	1299.1	125.3	9.7	26.6	2.2	13.6
Sample VIII		Warp	1298.6	103.1	7.9	25.8	2.9	11.4
		Weft	1240.8	98.2	7.9	25.6	2.4	9.4
Sample IX	Safety belt fabrics	Warp	10195.3	576.9	5.7	12.2	0.6	4.6
		Weft	4876.9	150.8	3.1	12.6	0.7	5.8
Sample X		Warp	9822.7	569.7	5,8	10.4	0.6	5.4
		Weft	4461.2	147.2	3.3	8.7	0.5	6.2
Sample XI		Warp	11232.5	617.8	5.5	10.8	0.5	4.6
		Weft	5966.1	274.4	4.6	11.4	0.7	6.1
Sample XII		Warp	12876.8	734.0	5.7	12.0	0.6	5.0
		Weft	6219.5	298.5	4.8	13.1	0.9	6.9

where: F – breaking force of yarn, cN, S – standard deviation, cN, CV – variation coefficient, % and I – elongation at break, %.

Experimental

The experimental investigations were performed in such a way that, in each case, four fabric samples for upholstering the motor vehicle interior design for airbags and safety belts were used.

Methods and instruments used in the experimental part

The STATIMAT M tensile tester by TEXTECHNO was used for testing the yarn breaking force and elongation at break. The yarn to be tested was pulled out from all the fabric samples and tested according to the ISO 2062 standard (HRN F.S2.052 standard). The fabric breaking force was tested according to the ISO 5081 standard (HRN F.S2.017 standard). The upholstery and airbag fabrics were tested on a tensile testing machine manufactured by Apparecchi Branca S.A. The breaking force of safety belts could not be tested with the fabric tensile tester. The Avery Tensile Tester, Model 7102CCH installed at the Končar Institute, intended for breaking metal wires, was used. During testing, fabric clamps were built in. The measuring range of the instrument amounts to 30,000 N. The testing conditions were adapted to the fabric standards. Resistance to the ball burst procedure was tested according to the HRN F.S2.022 standard. This investigation was performed only on the airbag and upholstery fabrics on the tensile tester of the company Apparecchi Branca S.A. The tearing of the airbag and upholstery fabrics was tested using a falling Elmendorf pendulum instrument manufactured by Henry Baer and Co. Ltd., according to the DIN 53862 standard. The air permeability of the airbag fabrics was tested on the air permeability tester of the company SDL Atlas, according to the EN ISO 9237 standard.

Testing materials

Four fabrics intended for upholstering car seats, four airbag fabrics and four narrow woven safety belt fabrics were tested. The upholstery fabrics were reinforced with a 1-2 mm thick polyurethane sponge on the back and with a thin warp knitted fabric (tricot/chain stitch). The fabric was woven in jacquard weaving with a combination of twill and sateen weaves and is intended for European cars. The airbag fabric specimens were tested directly before sewing. Safety belts were woven in widths of 4.6 (specimens IX and X) and 4.8 cm (specimens XI and XII). The specimens were woven in standard 2/2 twill weave with different combinations of broken twill.

Test results

Table 1 shows the basic parameters for the yarns and fabrics, whereas ***Tables 2*** to ***4*** show the test results of breaking force and elongation at breaks of yarns and fabrics, tear force, resistance to ball bursting and air permeability. The testing data were statistically analysed. To make individual parameters clearer, they are illustrated in the form of a graphical presentation (***Figures 4*** to ***6***).

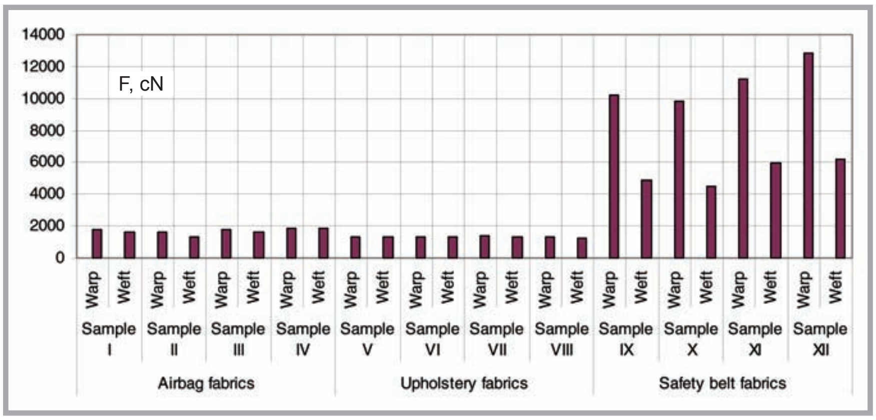

Figure 4. *Breaking forces of yarns.*

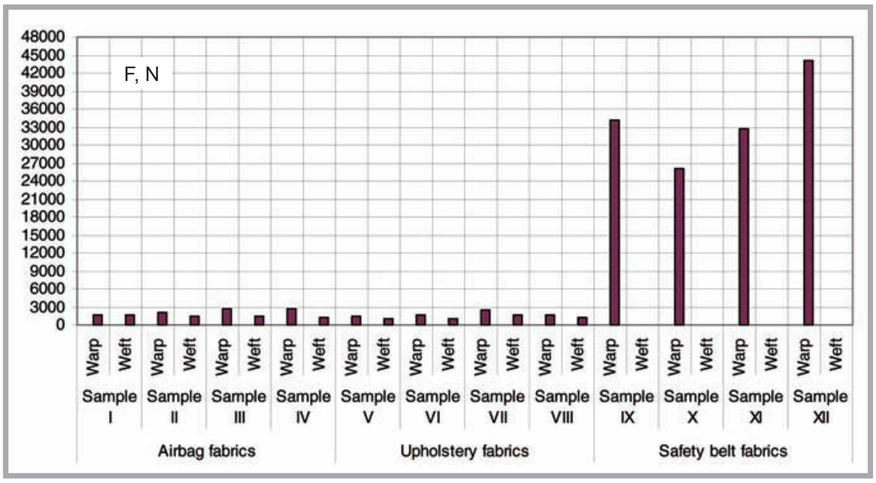

Figure 5. *Breaking forces of fabrics.*

Discussion

Based on the results reported in ***Tables 1*** to ***4*** and ***Figures 4*** to ***9***, the following may be concluded:

Motor vehicle fabrics for various purposes belong to the group of technical textiles. They have specific and very different properties designed to meet the target requirements.

Airbag fabrics are made as very dense synthetic fabrics almost exclusively woven in plain weave (***Table 1***). The warp and weft yarns are frequently of the same raw material composition and fineness, and are most frequently polyamide multifilament with a small difference in the weft and warp density. Samples of airbag fabrics tested in this investigation have a density of 180 to 211 ends/10 cm in the warp direction, and a density of 145 to 188 picks/10 cm in the weft direction. Warp density is higher than weft density in three samples; only sample I has the same density and fineness in the warp and weft directions. A very high, tight fabric construction was obtained in all the samples. The reason for this was the smoothness of the warp and weft yarns made of multifilament polyamide 6.6. The surface mass is relatively high and homogeneous, ranging from 228.8 to 291.6 g/m^2. The fabric made of a finer yarn has a higher density and vice versa, leading to a certain difference in fabric thickness ranging from 0.27 to 0.31 mm. The breaking force and elongation at break of the yarn used for manufacturing the air-

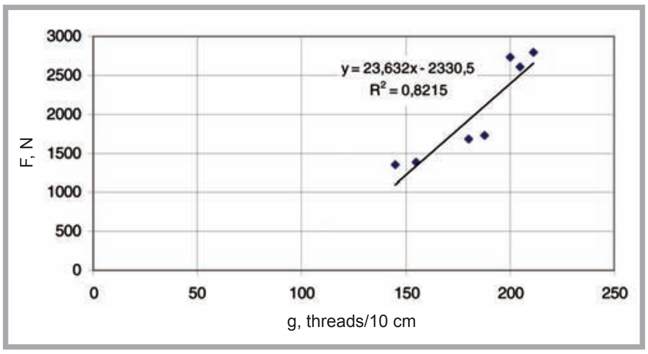

Figure 6. *Correlation coefficient and regression straight line of the breaking force of airbag fabrics and g – fabric density in the warp and weft directions.*

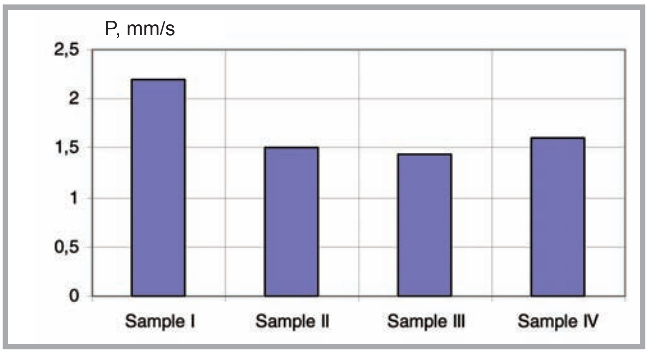

Figure 7. *Fabric air permeability of samples I, II, III and IV.*

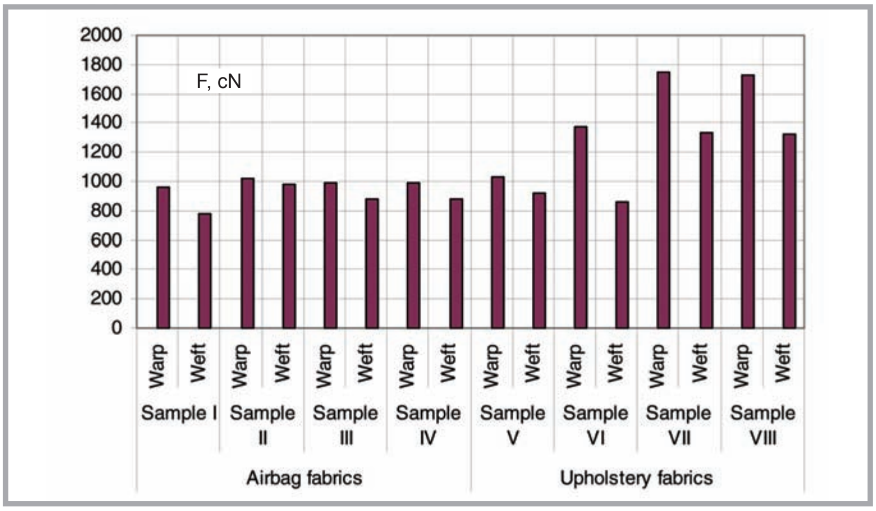

Figure 8. *Tear force of the fabric.*

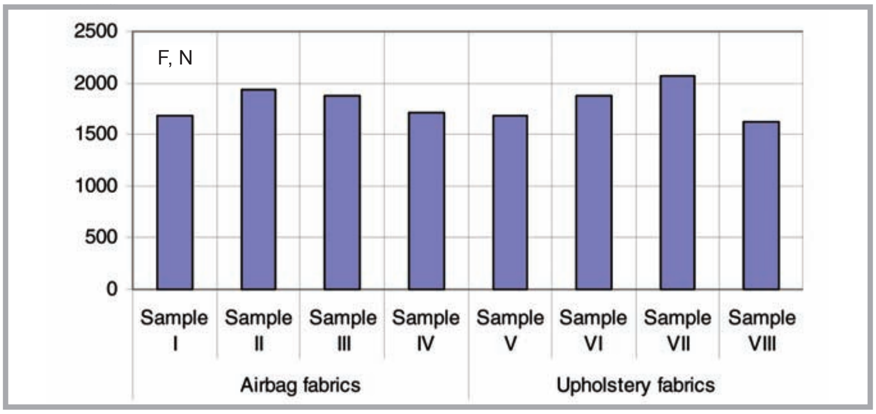

Figure 9. *Resistance of the fabric to ball bursting.*

bags dealt with in this paper was pulled out from the fabric in such a way that it had suffered certain changes during the weaving. After weaving and stabilizing the fabric, the warp threads had a breaking force from 1609.3 to 1887.5 cN, and the weft threads from 1325.5 to 1821.7 cN (***Table 2***, ***Figure 4***). The variation in the breaking forces of the yarn intended for the airbag was relatively small, especially of the warp threads (3.0–4.1%) in relation to the weft threads (4.4–5.4%). The elongation at break was also higher in the weft threads, amounting to a maximum of 23.5% in fabric samples I and IV.

Airbag fabrics feature not only high density and breaking forces of yarn, but also high fabric breaking forces, which should have been expected as a logical consequence (***Table 3***, ***Figure 5***). The fabric breaking force in the warp and weft directions correlates with the thread density confirmed with a high correlation coefficient of R2 = 0.9312 (***Figure 6***). The denser fabric had a higher fabric breaking force and vice versa, being confirmed by a high correlation coefficient, since the airbag, based on its shape and purpose, should have relatively homogeneous characteristics in the warp and weft directions in order to remain stable, safe and impermeable at the moment of deployment in the case of a car crash. The fabric breaking force in the warp direction ranges from 1688.1 to 3117.4 N and in the weft direction from 1343.2 to 1729.9 N.

One of the essential parameters of the safe action of the airbag is the permeability and impermeability of air, respectively. The air permeability of the tested samples ranges from 1.440–2.201 mm/s (***Table 3***, ***Figure 7***). The standard value deviation ranges from 3.2–4.9%, meaning that the fabric has very homogenous air permeability.

Table 4 shows the tested values of tear force and resistance to ball bursting in the samples of airbag and upholstery fabrics. These tests were not possible for safety belt fabrics so the samples from IX–XII were omitted.

The fabric tear forces of all the airbag fabric samples are several times lower than the breaking forces, ranging from 957.4 to 1022.4 cN in the warp direction, and they are slightly lower in all the samples in the weft direction, ranging from 779.1 to 981.5 cN (***Figure 8***). The resistance of the airbag fabric to ball bursting shows pretty homogeneous values in relation to the previous investigations (***Figure 9***). The reason for this probably lies in the fact that the warp and weft threads participate in this investigation. In this way, the difference in the breaking forces in the warp and weft directions becomes partially compensated for. Airbag fabric resistance to ball bursting ranges from 1687.0 to 1932.4 N. The breaking length is also homogeneous among the samples, ranging from 30.8 to 32.7 mm.

Fabrics for upholstering seats and other interiors of motor vehicles are often lined with a urethane sponge or knitted fabric and are woven in jacquard structures. This lined fabric provides comfort and softness in contact with the body; it is easier to form an ergonomic design of the seat and the residual interior. The task of the knitted fabric is to ensure a better adhesion of the sponge to the woven fabric, to protect it from damage and to provide better stability and elasticity of such a fabric. The samples of the fabrics tested for the purposes of this paper are lined with the same polyurethane sponge and knitted fabric, and therefore they were tested in this multi-layered form. As a rule, the density in the warp direction is higher (135–340 ends/10 cm) than the density in the weft direction (115–220 picks/10 cm), and these fabrics belong to the group of very dense fabrics considering the corresponding yarn count (***Table 1***). The warp and weft yarns are made of multifilament polyester with a count of 50 to 70 tex. The surface mass is relatively high, ranging from 291.5 to 402.4 g/m^2. The fabric thickness is increased by sponge and knitted fabric, ranging from 1.10 to 1.34 mm.

The tested yarns for upholstery fabrics suffered certain physical–mechanical changes because they were sampled from the fabric, as was the case with airbags. The obtained results show that the breaking force of the warp threads (972.4 to 1298.6 cN) always lies higher in all the samples than the breaking force of the weft threads (733.9 to 1299.1 cN), although they have the same or similar fineness and the same raw material composition (***Table 2***, ***Figure 4***). The reason for this effect comes from the specific number of twists in the warp thread, whereas this is not the case with the weft threads. The elongation at

Table 3. Investigation of breaking force and elongation at break as well as fabric air permeability; (–) not measured.

Fabric parameters to be tested			F, N	S, N	CV, %	I, %	S, N	CV, %	P, mm/s	S, N	CV, %
Sample I	Airbag fabrics	Warp	1688.1	87.8	5.2	23.9	1.3	5.4	2.201	0.1078	4.9
		Weft	1678.0	72.2	4.3	22.2	1.2	5.4			
Sample II		Warp	2788.4	161.7	5.8	23.5	1.1	4.7	1.511	0.0484	3.2
		Weft	1729.9	93.4	5.4	26.6	1.3	4.9			
Sample III		Warp	2605.3	122.4	4.7	24.8	0.9	3.6	1.440	0.0648	4.5
		Weft	1388.5	61.1	4.4	25.8	1.1	4.3			
Sample IV		Warp	2731.8	142.1	5.2	24.9	1.2	4.8	1.608	0.1078	3.3
		Weft	1343.2	60.4	4.5	25.1	0.9	3.6			
Sample V	Upholstery fabrics	Warp	1470.1	182.3	12.4	21.0	2.8	13.3	(–)		
		Weft	995.4	142.3	14.3	23.6	3.7	15.7			
Sample VI		Warp	1577.2	216.1	13.7	14.1	1.9	13.5			
		Weft	1011.1	147.6	14.6	19.1	2.6	13.6			
Sample VII		Warp	2388.3	324.8	13.6	31.5	4.5	14.3			
		Weft	1683.6	254.2	15.1	28.8	4.7	16.2			
Sample VIII		Warp	1728.1	254.0	14.7	35.7	4.7	13.2			
		Weft	1305.0	161.8	12.4	49.9	7.2	14.4			
Sample IX	Safety belt fabrics	Warp	24231.6	1369.3	5.7	18.1	1.3	7.2	(–)		
		Weft	–	–	–	–	–	–			
Sample X		Warp	26147.4	967.5	3.7	16.5	1.4	8.5			
		Weft	–	–	–	–	–	–			
Sample XI		Warp	32758.0	1441.4	4.4	19.9	1.9	9.5			
		Weft	–	–	–	–	–	–			
Sample XII		Warp	34078.6	2930.7	8.6	20.4	1.7	8.3			
		Weft	–	–	–	–	–	–			

where: F – breaking force of yarn, cN, S – standard deviation, cN, CV – variation coefficient, %, I – elongation at break, %, P – air permeability, mm/s.

Table 4. Investigation of tear force and resistance of fabric to ball bursting.

Fabric parameters to be tested			F_1 (cN)	S	CV (%)	F_2 (N)	S	CV (%)	*l* (mm)	S	CV (%)
Airbag fabrics	Sample I	Warp	957.4	40.0	4.2	1687.0	102.9	6.1	30.6	2.6	8.5
		Weft	779.1	4.7	0.6						
	Sample II	Warp	1022.4	38.9	3.8	1932.4	162.3	8.4	32.7	3.8	11.6
		Weft	981.5	14.7	1.5						
	Sample III	Warp	991.0	35.7	3.6	1870.1	151.5	8.1	30.8	2.3	7.5
		Weft	874.9	36.7	4.2						
	Sample IV	Warp	989.6	16.8	1.7	1711.4	169.4	9.9	32.0	3.4	10.6
		Weft	880.2	26.4	3.0						
Upholstery fabrics	Sample V	Warp	1025.6	82.0	7.8	1680.6	197.13	11.73	29.4	3.06	10.41
		Weft	920.9	83.1	9.0						
	Sample VI	Warp	1374.4	53.4	3.9	1877.3	257.19	13.70	31.4	3.35	10.66
		Weft	860.5	72.0	8.4						
	Sample VII	Warp	1745.5	150.1	8.6	2074.1	292.43	14.10	32.8	4.10	12.50
		Weft	1332.9	126.6	9.5						
	Sample VIII	Warp	1729.2	153.9	8.9	2026.5	254.13	12.55	28.0	2.72	9.73
		Weft	1321.6	118.9	9.0						

where: F_1 – tear force (N), F_2 – resistance of fabric to ball bursting (N), l – breaking length (mm).

break of the warp thread ranges from 25.7 to 27.4%, and from 25.6 to 27.0% for the weft threads, but the differences between the warp and weft threads in the samples are relatively small.

The upholstery fabrics have a relatively high breaking force, ranging from 147.1 to 2388.3 N in the warp direction, and from 995.4 to 1638.6 N in the weft direction (***Table 3***, ***Figure 5***). These relatively high values of the breaking forces resulted from the knitted fabric and polyurethane sponge glued to the fabric back. The breaking forces are different in the samples in the warp and weft directions. The reason for this effect is a difference in the yarn density and fineness. Denser fabrics and coarser yarns have higher breaking forces, as is the case with sample VII having the highest breaking forces and the highest densities, whereas in the case of sample V, the lowest breaking forces densities can be observed, but also the sample with the finest yarn. Elongation at break is mostly higher in the weft direction, although the breaking force is lower, ranging from 14.1 to 35.7% in the warp direction, and from 19.1 to 49.9% in the weft direction.

On average, the tear force in the samples of upholstery fabrics is slightly higher than in the samples of airbag fabrics, although it is the inverse situation if the breaking force of the fabrics is considered. The reason for this effect is to be found in the knitted fabric and partly in the polyurethane sponge on the fabric back creating additional resistance to tearing of the upholstery fabric. The tear force of the upholstery fabric ranges from 1025.6 to 1745.5 cN in the warp direction, and from 860.5 to 1332.9 cN in the weft direction (***Table 4***, ***Figure 8***).

The process of airbag fabric resistance to ball bursting mostly followed the process of tear force and breaking force of the fabric. Sample VII has the highest resistance to bursting (2074.1 N), the highest tear force in the warp and weft directions and the highest breaking force in the warp and weft directions (***Table 4***, ***Figure 9***). Sample V has the lowest resistance to bursting (1680.6 N), the lowest tear force in the warp direction and the lowest breaking force in the warp and weft directions. The breaking length in the case of the bursting test was uniform, ranging from 28.0 to 32.8 mm.

Safety belt fabrics also require specific qualities and manufacturing. They belong to the fabric group that has the highest density in the warp direction. The samples tested had a density in the warp direction of 585 to 700 ends/10 cm, and in the weft direction from 140 to 150 picks/10 cm (***Table 1***). Multifilament polypropylene yarns with high densities are used to obtain the appropriate density, and thus the appropriate strength, of safety belts. The fineness of the warp threads in the tested samples ranges from 180 to 190 tex, and the fineness of the weft threads ranges from 65 to 90 tex. The weave type mostly used is broken twill weave, which has the same number of warp and weft crossing points in the weave unit, being the basic weave (K2/2) with broken contours in the weave unit. By using these weave types with very high densities in the warp direction, a thicker fabric is produced because the warp threads are combined into four layers. Due to a relatively high density in the warp direction, these fabrics have a very high surface mass, ranging from 1240 to 1375 g/m^2. The reason for this is a relatively great fabric thickness, ranging from 1.19 to 1.28 mm in the tested samples.

By pulling the yarn from the fabric, the breaking force and elongation at break of the yarn for safety belts were tested. Based on the results obtained, it is evident that this yarn surpassed the breaking forces of the yarn from the previous fabrics several times, ranging from 9,822.7 to 12,876.8 cN, which may be correlated with high tex values and a coarse yarn, respectively (***Table 2***, ***Figure 4***). Weft threads also have a relatively high breaking force, ranging from 4461.2 to 6219.5 cN. Fluctuations in the mean value of the breaking forces of the yarn are higher in the warp direction, ranging from 5.5 to 5.8%. Elongation at break in the warp direction ranges from 10.4 to 12.2%, and in the weft direction from 8.70 to 13.10%.

The breaking force of the safety belt fabrics was tested only in the warp direction; it was impossible to test in the weft direction due to the small safety belt width (4.6 and 4.8 cm). The breaking force in the warp direction was tested over the whole width of the safety belt and over a length of 20 cm. The tested values of the breaking forces are extraordinarily high, ranging from 24,231.6 to 34,078.6 N, and elongation at break ranges from 16.5 to 20.4% (***Table 3***, ***Figure 5***).

Conclusions

The results obtained show the following: According to the analysis of motor vehicle fabrics, they are divided as follows: fabrics for upholstering car seats and inside the interior and fabrics for passenger safety, which are divided into airbag fabrics and safety belt fabrics. Although these fabrics belong to the same group, i.e. technical textiles, motor vehicle fabrics differ in their properties and manufacturing processes. Upholstery fabrics are woven on jacquard weaving machines, airbag fabrics are woven on cam looms and safety belt fabrics are woven on narrow fabric weaving machines. These fabrics have extremely high densities and strengths; they are made from synthetic multifilament yarns, which can meet these demands.

Comfort, strength, aesthetics, elasticity, abrasion and fire resistant, colour fastness, ventilation and insulative properties are essential properties expected of fabrics for seat upholstery and motor vehicle interior design. Air impermeability, strength and shape are essential properties that an airbag should possess so that its action in the case of an accident can be effective. The effectiveness of airbags is due to the use of the seat belts. Safety belts are crucial for passenger safety in the vehicle because they keep the body in the proper position at the moment of a crash and the contact with the airbag.

According to the results obtained, it may be concluded that fabrics, depending on their use in vehicles, have very different properties imposed during their design. However, materials for the same use have almost the same or very similar qualities because of stringent requirements.

❑

Acknowledgement

The results shown in the paper resulted from the scientific programmes (Advanced Technical Textiles and Processes, code: 117-0000000-1376; Anthropometric Measurements and Adaptation of Garment Size System, code: 117-1171879-1887) conducted with the support of the Ministry of Science, Education and Sports of the Republic of Croatia.

References

1. *Ronghua Y., Liangji L.: Proceedings of 5th International Conference on Man-Made Fibre, Beijing, 1994, 475-484.*
2. *Čunko R.: Tekstilije – važna komponenta u suvremenoj proizvodnji automobila, Tekstil, 55 (6) 279-290, 2006.*
3. *Mukhopadhyay S. K., Patridge J. E.: Automotive Textiles, Textile Progress, The Textile Institute Manchester, 1999, 29.*
4. *http://www.autoweb.hr/article.php?story=20051108075841816, 25 September 2006.*
5. *Radmanović D.: Analiza tkanina za zračne jastuke, diplomski rad, Tekstilno-tehnološki fakultet, Sveučilišta u Zagrebu, 2005.*
6. *Kovačević S., Vitez D., Ujević D.: Analiza tkanina za zračne jastuke, Tekstil 54 (7) 326-331, 2005.*
7. *Ujević D., Kovačević S., Wadsworth L. C.: Textile in a Function of Car Industry, The 5th International Scientific Conference of Producing Engineering, Development and Modernization of Production, University of Bihać, RIM, 2005.*
8. *Ujević D., Brnada S., Kovačević S.: Production of Airbag Fabrics, Cotton Utilization Conference: Nonwovens, January 3-6, San Antonio, Texas, 2006.*
9. *http://www.index.hr/clanak.aspx?id=290098, 25 September 2006.*
10. *http://auto.blogger.ba/blog.godina=2004&mjesec=12&dan=1php?blog=auto&8, 30 October 2006.*
11. *http://www.vidiauto.com/01novosti/index.php?id=1689, 30.10.2006.*
12. *Technical information ed. Schmetz Co., Germany, IMB, 2006.*
13. *Technical information ed. Dürkopp Adler Co., IMB, 2006.*
14. *Technical information, Tekstil, 52 (12) 640-641 (reprint: Melliand International 9, 225, 2003).*
15. *http://commons.wikimedia.org/wiki/Image:Seatbelt.png, 30 October 2006.*
16. *http://www.nhtsa.dot.gov/people/injury/airbags/buckleplan/Internet_Services_Group/ISG-Restricted/BuckleUp%20America/pregnancybrochure/page2.html, 30 October 2006.*

❑ ***Received 8.03.2007 Reviewed 4.04.2008***