Permeability properties of woven fabrics containing two-ply fancy yarns

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ABSTRACT – REZUMAT

Permeability properties of woven fabrics containing two-ply fancy yarns

The basic intention of the presented research is to analyse the permeability properties of woven fabrics containing two-ply fancy yarns in the weft direction. Within the framework of presented research, two-ply fancy yarns were analysed. Because of their structure, they are classified as fancy yarns with structural effects. The first analysed two-ply fancy yarn is made of the mixture of 81% cotton and 19% viscose. The second is made of the mixture of 67% viscose and 33% flax. For the purpose of the presented research, woven fabrics containing two-ply fancy yarn were made in three different densities in weft (10 threads per cm, 13 threads per cm, and 16 threads per cm) in the twill weave T 1/3 Z. The theoretical part includes the historical development of the production of the fancy yarns, a detailed discussion of the ring production processes, the types and the structure of the fancy yarns, their use, and the global and European market of the fancy yarns. The experimental part consists of three parts. In the first part, the structural properties of the analysed fancy yarns were researched (the fineness of the fancy yarn, the frequency of repeating the effects per one meter of the yarn, the direction of twisting the fancy yarn, the number of the twists of the basic and the effective part, the diameter of the fibers, the diameter of the basic and the effective part, the fineness of individual components, the direction of the twist of individual components, and the percentage of the inside twist of individual components). In the second part, constructional properties of the analysed woven fabrics with the fancy yarn in the weft were researched (mass, thickness, the density of the warp and weft threads, and openness of the surface). In the third part, permeability properties of the analysed woven fabrics with the fancy yarn in the weft were researched where greater attention was paid to air permeability and water vapour permeability. The results of the research showed that the samples with the first two-ply fancy yarn in the weft (81% cotton and 19% viscose) have greater air permeability and water vapour permeability. Meanwhile, the samples with the second two-ply fancy yarn in the weft (67% viscose and 33% flax) have lesser abrasion resistance and poorer dimensional stability while being washed.

Keywords: *two-ply fancy yarn, air permeability, water vapour permeability*

Permeabilitatea țesăturilor ce conțin fire fantezie dublu răsucite

Obiectivul studiului este de a analiza permeabilitatea țesăturilor ce conțin fire fantezie dublu răsucite în direcția bătăturii. În cadrul acestui studiu, au fost analizate firele fantezie dublu răsucite. Datorită structurii lor, acestea sunt clasificate ca fire fantezie cu efecte structurale. Primul fir fantezie dublu răsucit analizat este fabricat din amestec de 81% bumbac și 19% viscoză. Al doilea este compus din amestec de 67% viscoză și 33% in. În scopul studiului prezentat, țesăturile ce conțin fire fantezie dublu răsucite au fost realizate în trei desimi diferite în bătătură (10 fire per cm, 13 fire per cm și 16 fire per cm) cu legătură diagonal T 1/3 Z. Partea teoretică include istoria producției de fire fantezie, o discuție detaliată a proceselor de producție, tipurile și structura firelor fantezie, utilizarea acestora și piața globală și europeană a firelor fantezie. Partea experimentală este formată din trei părți. În prima parte, au fost analizate caracteristicile structurale ale firelor fantezie (finețea firului fantezie, frecvența de repetare a efectelor per metru de fir, direcția de răsucire a firului fantezie, numărul de răsuciri ale părții de bază și ale celei efective, diametrul fibrelor, diametrul părții de bază și a celei efective, finețea componentelor individuale, direcția răsucirii componentelor individuale și procentul răsucirii în interiorul componentelor individuale). În a doua parte, au fost analizate caracteristicile țesăturilor cu firul fantezie în bătătură (masă, grosime, desimea în urzeală și în bătătură). În a treia parte, a fost analizată permeabilitatea țesăturilor cu firele fantezie în bătătură, unde s-a acordat o mai mare atenție permeabilității la aer și permeabilității la vapori de apă. Rezultatele studiului au arătat că probele cu primele fire fantezie dublu răsucite în bătătură (81% bumbac și 19% viscoză) au o permeabilitate mai mare la aer și la vapori de apă. Pe de altă parte, probele cu al doilea fir fantezie dublu răsucit în bătătură (67% viscoză și 33% in) au avut o rezistență mai mică la abraziune și o stabilitate dimensională mai slabă la spălare.

Cuvinte-cheie*: fir fantezie dublu răsucit, permeabilitate la aer, permeabilitate la vapori de apă*

INTRODUCTION

The term "fancy yarn" refers to yarns containing deliberately planned irregularities, which make them distinct from classical yarns or multifilament ones. Fancy yarns represent only a few percent of the total world production earlier, their process is longer and slower, which is why they are considered special products and their price is much higher [1–5]. Fancy yarns, especially two-ply, on the other hand, are increasingly relevant in the fashion industry. This is also the main reason why our research focuses on two-ply fancy yarn which is produced with ring process and is most commonly used for high-quality garments. Some authors in the literature are also concentrated on the quality of fancy yarns in the last five years [6, 7]. Few papers also mention the evaluation of air permeability of fabrics woven with slub yarns [8] and also the performance of knitted fabrics produced from fancy yarns [9]. Some authors are also concentrated on efforts to methodise, problems and new suggestions of fancy yarns production [10] and also on comparison between ring spun and also fancy yarns [11].

The purpose of the presented research was to investigate the influence of two-ply fancy yarn on the permeability properties of woven fabrics with fancy yarn in the weft direction. Two different two-ply fancy yarns were analysed, both of which consist of a basic and effective component, which, due to the structure with the thickened places, belonged to fancy yarns with structural effects. Within the framework of the research, six fabrics were made from fancy yarns in the weft direction. The warp was in all samples from the classical ring spun yarn (100% cotton), and the weft in the first three samples from a two-ply fancy yarn, where one component is made of ring spun yarn, while the second one consists from multifilament yarn (81% cotton and 19% viscose), and in the other three samples from the two-ply fancy yarn, more precisely two single ring spun yarns (67% viscose and 33% flax). Woven fabrics were woven at three different densities in the weft (10 threads/cm, 13 threads/cm and 16 threads/cm) and the same densities in the warp direction (20 threads/cm) in the twill weave T 1/3 Z. More attention was paid to air permeability and water vapour permeability. Abrasion resistance and dimensional stability in the washing of analysed fabrics with fancy yarn were also investigated. The results of the presented research will show the effect of two-ply fancy yarn in the weft direction on the permeability properties of analysed woven fabrics.

THEORETICAL PART

Historical development of the production of fancy yarns

It is not known exactly when we first encountered fancy yarns, since there is not much tangible evidence of their emergence. The claims argue that this is primarily a conclusion based on archaeological finds in the old graves, that they had effective beginnings early in the early weavers, which should be used during the weaving in various ways to achieve a wide spectrum of color and structural effects. The mentioned weavers are also supposed to be able to anticipate texture changes that would result from differences in yarn thickness. Thus, the yarn produced would correspond to a pre-planned sample and structure [1, 2].

Unlike other fancy yarns, it is easier to find evidence of metal yarns confirming that Egyptians and Babylonians used them in ritual and ritual clothing materials. The yarn from that time was not permanent and thoughtful, but they were a cheap way to achieve the effects. Throughout history, metallic yarns have been used in different periods, including Elizabeth and their contemporaries all over Europe for embroidering and making lace. Findings prove that metal yarns used for decorating in the sixteenth and seventeenth centuries consist of thin metal strips wrapped around a silk or flax core [1, 2].

One important statement claims that in the eighteenth century, yarns made from a bundle of silk filaments tied around the silk core were often used. The resulting effect was referring to the chenille yarn, which made it possible to conclude that this was perhaps the first real two-ply fancy yarn that was developed. There are conclusions based on the records that in the aforementioned century there were four basic types: the so-called classic yarn consisting of fine stripes wrapped around the core; a spiral yarn containing two yarns wrap around the core; flattened yarn, composed of a straightened metal wire and a metal effective double yarn, consisting of a flat yarn wrapped around the spiral thread [1, 2].

It has been proven that at the end of the nineteenth century, the development of fancy two-ply yarns, as we know it today, has begun, and with it an increase in the volume of devices intended to produce special effects. With the prevalence of an improved electronically controlled process in the late twentieth and early twenties, it was easier to produce diverse effects while maintaining a uniform level of quality [1, 2].

Production process of fancy yarns

Over the years, many different methods have been developed to produce fancy yarns. Among the main four today are the ring process, a hollow spindle process, a combined process, and a process for the manufacture of chenille yarn. Unlike the first three mentioned processes that produce several visually similar types earlier, the process for production chenille yarns is considered to be less versatile since it produces only one type of yarn. In addition to the four main procedures, there is also a dual process, a condenser process, a rotor process, a friction process, and air-jet process [2]. Most of the fancy yarns are made by the ring process. Thus, more attention in the paper is given to the fancy yarns which are produced using ring process. [2, 3]

Production of fancy yarns using the ring process

In spite of the modern spinning processes used in the past twenty years to produce the fancy yarns, the ring process remains the leader in the spinning field, as it is still produced approximately eighty percent earlier [2]. In the case of a ring process, the proposed roving is supplied through a three roller and two aprons draw frame. The first pair of rollers that feeds the roving are called the feed or back rollers and the last pair, which separates the thinned formation - yarn, are called the front rollers. Between feeding and front rollers are the so-called apron rollers, with upper and lower apron, which allow for controlled control of fibers in drawing zone of the draw frame. After drawing, it is followed by reinforcement with a twisting at the same time winding the yarn onto the cops [2].

The yarn that leaves the spinning roller and passes through the thread guide, which is located exactly above the ring spindle, is provided with the help of the ring-traveller-spindle mechanism. Produced yarn is wound on the kops after transmitting the vitle in the same place. Cops is mounted on the spindle and spins with it. During its rotation, the tension is drawn by a runner circling the circumference of the ring, and in this way it transmits the real twist to yarn. The height of the yarn winding is regulated by the train on which the spindle is installed. The train rises and descends all the time to wind down the so-called filling and separation layers, then rises gradually to a higher level, until the entire layer is wound up on the cops [2].

The ring process is regarded as the most flexible, as it is possible on the ring tower to retrofit a mechanical or electronic control device that allows programmed effects to be produced, such as thickened, thinned effects and different turns per yarn length.

The thickness of the yarn length is achieved by the programmed and controlled steering of the stepping motor, which drives the feeding and pulley roller in a simple binary expansion. The effect of the thickened place is achieved by briefly accelerating the rotation of the feed roller at the unchanged rotational speed of the discharge cylinder in the extender. The length, intensity and repetition of the effects are controlled by the settings of the control unit. A variety of turns per length of fancy yarn is achieved by changing the rotational speed of the spindle during the transmission of the real twist to produced yarn [1–4].

The main disadvantage of producing fancy yarns after the ring process is in long-lasting and costly manufacturing processes. Fancy yarns composed of one or more basic, one or more effective and, in most cases, binding yarns, are made in two or more separate transitions of the ring spinning machine in the ring process to produce fancy yarns [1, 2].

The production of loops and lace yarns, consisting of two basic components, supplied over a pair of feed rollers and a fancy yarn, supplied with a pair of rollers. Since they are supplied at different speeds, the base yarns are able to pass through groove slits on the upper separating cylinder, allowing the base and effective grooves to merge when leaving the separating rollers. The resulting triangle represents an area where the excessive effect produces loops or laces. The size of the effects is regulated by changing the size of the spin triangle while it is regulated by changing the tension during spinning, the twist degree and the groove of the upper roller [1, 2].

When the fancy yarn is much thicker than the base, the roller is replaced by a smooth top roller so that it is raised and the pressure can be applied to the base yarn. This feeder system also applies to fancy yarns that contain only one basic component [1, 2].

The global and European marketplace of fancy yarns

Over the last decade, there has been a noticeable increase in the worldwide interest in the production of fancy yarns worldwide, which is expected to grow steeply in the next decade following the latest market research. The reason for the interest is most likely due to the liberalization of the international market of fancy yarns between Asia and Europe, which are the largest exporters and dominate the field of production. In addition to the Asian countries, including China, Japan, Korea and India, and Europe, which is in favor of Germany, France, Great Britain, Russia and Italy, the production of effects has already taken place in North America, South America and Africa. In recent years, lower production has been observed. The most demand and consequently the production is intended for chenille, ondé, gimp and loop, lace and flame fancy yarns. When it comes to the effect of the market of fancy yarns earlier, it should be noted that their use is not so common, and that their market value will continue to be unparalleled in comparison with the rest of the textile market [4, 5].

The latest trends in the yarns production field foresee a bright future for fancy yarns, as they will continue to be present in knitted clothes, which will be radiant appearance, due to the influence of various metallic colors, loose vitters, small knots and various large flames [10–12]. The worldwide market for fancy yarn is expected to grow at a CAGR of roughly 5.6% over the next five years, according to a new Global Info Research study. This information focuses on the fancy yarn in global market, especially in North America, Europe and Asia-Pacific, South America, Middle East and Africa [13].

EXPERIMENTAL PART

Presentation of analysed fancy yarns and fabrics with fancy yarns

In the experimental part, two-ply fancy yarns were analysed, both of which consist of a basic and effective component that produces effects at intervals. The first analysed fancy yarn labeled FY1 is a two-ply fancy yarn, made of cotton ring spun yarn which is plied with viscous multifilament yarn. The ratio of the both components in the mixture presents 81% cotton and 19% viscose, while the second analysed two-ply fancy yarn, labeled FY2, from two single ring spun yarns from a mixture of 67% viscose and 33% flax. Because of their recognizable effects, which are visible as bold spots with fewer turns, they belong to the fancy yarns with structural effects. They are made by ring process, on the bobbin twist of the Alma Saurer machine. Table 1 presents the structural properties of the analysed two-ply fancy yarns.

In table 2, the structural properties of the individual components of the analysed two-ply fancy yarns are presented earlier.

Table 1

STRUCTURAL PROPERTIES OF ANALYSED FANCY YARNS			
Sample	**Yarn structure**	**Fineness (tex)**	**Frequency of repetition of effects on meter of yarn (%)**
FY1	Two-ply fancy yarn	180	23
FY2	Two-ply fancy yarn	230	17
Sample	**Twist direction (S/Z)**	**Number of twist of basic part (T/20 cm)**	**Number of twist of efective part (T/10 cm)**
FY1	S	88	40
FY2	S	52	10

Table 2

STRUCTURAL PROPERTIES OF THE INDIVIDUAL COMPONENTS OF THE ANALYSED TWO-PLY FANCY YARNS						
Sample	**Diameter of fibres d_v (μm)**		**Diameter of basic part of fancy yarn d_t (μm)**		**Diameter of efective part of fancy yarn d_e (μm)**	
FY1	Component1	Component2	Component1	Component2	Component1	Component2
	21.7	33.3	757	343	1995	351
FY2	Component1	Component2	Component1	Component2	Component1	Component2
	17.5	12.7	622	614	625	1415
Sample	**Fineness T_t (tex)**		**Twist direction (S/Z)**		**Percent of twist P_v (%)**	
FY1	Component1	Component2	Component1	Component2	Component1	Component2
	146	34	S	S	4	0.8
FY2	Component1	Component2	Component1	Component2	Component1	Component2
	117	113	Z	Z	0.8	0.8

Note: FY1 – Component1 (cotton ring spun yarn), Component2 (viscose multifilament yarn); FY2 – Component1, Component2 (single ring spun yarn from the mixture of viscose and linen).

Table 3

STRUCTURAL PROPERTIES OF FABRICS WITH TWO-PLY FANCY YARN IN WEFT				
Sample	**Density on the weaving machine (threads/cm)**		**Mass M (g/m^2)**	**Thickness d (mm)**
FY1_10	Warp	Weft	231.8	1.120
	20	10		
FY1_13	Warp	Weft	303.9	1.157
	20	13		
FY1_16	Warp	Weft	351.9	1.174
	20	16		
FY2_10	Warp	Weft	286.7	0.980
	20	10		
FY2_13	Warp	Weft	339.4	0.984
	20	13		
FY2_16	Warp	Weft	369.9	0.992
	20	16		
Sample	**Warp density (threads/cm)**		**Weft density (threads/cm)**	**Openess of area (%)**
FY1_10	24		13	8.74
FY1_13	26		15	3.96
FY1_16	28		18	3.19
FY2_10	25		14	4.58
FY2_13	27		16	3.54
FY2_16	29		19	2.35

Presentation of analysed fabrics with two-ply fancy

In the framework of the research, the woven fabrics in the twill weave T 1/3 Z were analysed with the two-ply fancy yarns in the weft direction which are marked with FY1 and FY2. The classical ring spun cotton yarn was used in the warp direction. Woven fabrics were made at three different densities in the weft, namely 10 threads/cm, 13 threads/cm and 16 threads/cm, with a density of 20 threads/cm in the warp direction, on the weaving machine Minifaber with TIS electronic jacquard mechanism. The designation of the samples consists of a series of analysed effects of the earlier and number of weft threads per centimeter. Table 3 presents the structural properties of fabrics with two-ply fancy yarn in weft.

Table 4 shows the properties of the ring spun cotton yarn in the warp direction.

Table 4

PROPERTIES OF THE RING SPUN COTTON YARN IN THE WARP DIRECTION

Sample	Yarn	Fineness (tex)	Number of twist (T/m)
Warp	Ring spun	16 (2·8 tex)	542 Z

Presentation of the methods used

The fineness of fancy yarn

Fineness or linear density is a physical quantity that is defined as mass per unit length. It provides the most useful way of expressing fineness that affects the properties of yarn. The length of the mass is determined indirectly, by compression, capacitive methods or direct, gravimetric determination [12, 14, 15].

Method of work:

The linear density of fancy yarns has been measured in accordance with ISO 2060 Textiles – Yarn from packages – Determination of linear density (mass per unit length) by the skein method [16]. A gravimetric method was performed whereby the measured length of two-ply fancy yarn which amounts 1 m was weighed. Twenty measurements were made for each sample of the analysed fancy yarn and individual components. From the readings of the measured mass of the fancy yarn sample and the individual components, the average value of the linear density was calculated according to the equation:

$$T_t = \frac{m \cdot 10^3}{l} \tag{1}$$

where T_t is linear density (tex), m – mass of yarn (g), l – length of yarn (m).

The twist direction of two-ply fancy yarn

During the spinning process, a yarn is formed by the inserting twist, which is defined by the twist direction (left or right) and the number of turns. The direction of the twist is indicated by the capital letters S or Z. When the turns of the yarn are in the left direction, the yarn has so-called S-twist, when they are in the right direction, the yarns has so-called Z-twist. The direction of the coil is determined optically or on a device for measuring the number of turns called the Torsiometer [12, 14, 15].

Method of work: the twist direction of the two-ply fancy yarn was previously determined in accordance with the ISO 2 standard, Textiles – Designation of the direction of twist in yarns and related products [17]. Optical determination of the winding direction and determination of the torsiometer for each sample of the analysed two-ply fancy yarn and its individual components were carried out. The direction of the twist was indicated by a capital letter, where the mark S represents the left twist and the mark Z indicates the right twist of the yarn.

The number of twist of two-ply fancy yarn

The number of twist is very important for mechanical properties of yarn, which include breaking strength, elongation, and elasticity. The number of twist also influences on appearance of the yarn. The number of twist of single yarn is determined indirectly by measuring the number of turns required to completely unroll the yarn and then twisting in the opposite direction to the original number of turns, while the number of turns of ply yarn is determined directly, at thus measuring the number of turns required to completely unroll the yarn [12, 14, 15].

Method of work: the number of twist was previously determined in accordance with ISO 2061, Textiles – determination of twist in yarns – Direct counting method [18]. A direct determination of the number of turns of two-ply fancy yarn was carried out on a Torsiometer device. First, the aforementioned determination of the pattern direction of the sample was carried out. A preparatory needle was used to help separate the individual components. When these two were completely unwound, the number of turns from the differential counter was read. Twenty-five measurements were made for each sample of the analysed fancy yarn. Due to the presence of effects occurring at intervals, the turns were measured to be 20 cm at the base part and at 10 cm at the effect part. From the readings of the measurements of the fancy yarn sample, the average value of the number of turns was calculated.

Percent of twist of two-ply yarn components

The percent of twist is defined as a change in the length of the plies, which is seen as an extension of the component when unwinding the yarn twisted. It is dependent on the different characteristics of yarn, which include the composition, the length and direction of the twist. The percent of twist is determined by measuring the initial length of plied yarn and the final, unwinding length, after untwisting [14].

Method of work: measurement of the percent of twist of each component was carried out in such a way that the individual components of the sample of two-ply fancy yarn of an initial length of 10 cm were untwisted. After untwisting, the length of each component was re-measured. Ten measurements were made for each sample of the analysed fancy yarn.

From the value of the final length of the individual components of the fancy yarn, the mean value of the percent of the twist was calculated according to the equation:

$$P_v = \frac{l_k - l_z}{l_z} \cdot 100 \quad (2)$$

where P_v is percent of twist (%), l_k – final length after untwisting (cm), l_z – initial length of two-ply yarn (cm).

Mass of fabrics with fancy yarn

The surface mass is defined as the mass per unit area in g/m^2. The mass of a square meter of textile material is determined by accurately measuring the cut-out sample of a given size, usually 10×10 cm while the mass of the running meter is determined by accurately measuring the mass of the entire width of the sample at one-meter length [12, 14].

Method of work: the surface mass of fabrics with fancy yarn was measured in accordance with SIST EN 12127, Textiles – Fabrics – Determination of mass per unit area using small samples [19]. The measurement of the square mass of the square meter was carried out in such a way that the fabric sample with dimension 10×10 cm was weighed. Five measurements were made for each fabric sample with the fancy yarn. From the readings of the measured mass of the fabric sample, the average value of the surface mass was calculated according to equation:

$$M = \frac{m \cdot 10^4}{S} \quad (3)$$

where M is fabric surface mass (g/m^2), m – fabric weight (g), S – fabric surface (cm^2).

Thickness of fabrics with fancy yarn

Thickness is defined as the measurement of height between two parallel surfaces separated by a textile material at a specified pressure. When measuring thickness, the shape and size of the pressure leg, measurement time, and pressure should be taken into account. The thickness affects the insulation and permeability properties of the textile material [12, 14].

Method of work: the thickness of fabrics with fancy yarn has been measured in accordance with ISO 5084, Textiles – Determination of thickness of textiles and textile products [20]. The thickness measurement was performed on a device called Micrometer at a pressure of 20 cN/cm^2. Five measurements were made at five different locations for each fabric pattern. From the average measurements of the fabric sample, the average thickness value was calculated and expressed in mm.

Density of fabrics with fancy yarn

The density of the weave is defined by the number of warp and weft threads per unit length. The air permeability and thermal conductivity of the textile material depend to a large extent on the density of the warp and the weft. It is determined by counting and given by the number of threads/cm [12, 14].

Method of work: the density of fancy yarn fabrics has been measured in accordance with SIST EN 1049-2, Textiles – Woven fabrics – Construction – Methods of analysis – Part 2: Determination of number of threads per unit length [21]. The warp and weft density of the fabric was measured using a thread counter (frame magnifier with surface of 1 cm^2) by counting the warp threads at five different locations along the entire width of the fabric, while the weft threads were counted at five places the length of the fabric, as far apart as possible. From the values of the warp and weft threads of each fabric sample with fancy yarn, the average density value was calculated.

Openness of the area of fabric with fancy yarn

The surface openness is defined as the empty spaces between the warp and weft threads in the fabric and the empty spaces between the fibers in nonwoven fabrics. It is determined by image analysis using ImageJ (free program by Wayne Rashband, National Institute of Health, United States of America) and reported in percentages [14].

Method of work: the measurement of the surface area of the fancy yarn fabrics was carried out by image analysis, using a shot of the analysed sample of the yarn fabric, using ImageJ [23]. The image was previously recorded on a Leica stereomicroscope at 10x magnification. Three measurements were made for each fabric sample. From the measured values of the fabric sample measurements, the average value of the openness of area was calculated.

Air permeability of fabrics with fancy yarn

Air permeability is defined as the airflow velocity that passes perpendicularly through the textile material on a given surface, pressure and time. It is measured as the amount of air passing through 1 m^2 of textile material within 1 minute at the selected pressure. Air permeability is one of the most important properties that affect porosity, insulating properties, rain and wind protection, and filtering ability. To a large extent, it depends on the structural properties of textile material, which include yarn properties, weave and density of the thread [12, 14].

Method of work: the air permeability of fabrics with fancy yarn was measured according to SIST EN ISO 9237; Textiles – Determination of the air permeability of textiles [23]. Measurement was carried out on the air-permeability measuring device, called AirTronic 3240A, with a measuring surface of 50 cm^2 and a selected pressure of 100 Pa. Through the sample, the air was passed, which passed through the measuring system, which showed the quantity of air in [l/h]. Ten measurements were made at different places of each fabric sample with fancy yarn. The average value of the air permeability was calculated from the readings of the measurements of the sample of the fabric with fancy yarn.

Water vapour permeability of woven fabrics with fancy yarn

The water vapour permeability is defined as the amount of water vapour that passes through 1 m^2 textile material in a given area within 24 hours. The

water vapour permeability is influenced by the structural properties of textile material, which include the construction properties of fabric, chemical composition of yarn and the density of the thread. It can be determined by the method with water or by the method using a drying agent [12, 14].
Method of work: the permeability of water vapour of woven fabrics with fancy yarn was measured according to ASTM E96/E96M; Textile – Determination of water vapour permeability [24]. The measurement was carried out using the water method, where the sample was embedded in a glass container with a metal cover, 3 cm in diameter, containing 7 ml of distilled water. A glass container with a sample was inserted into the desiccator. After 1 hour of standstill at room temperature, the prepared sample container was weighed on an electronic weigh and then after 24 hours of rest in the desiccator, thus eliminating the influence of moisture. Two measurements of each sample of the fabric with fancy yarn were made. From the measured mass of the sample of the fabric with fancy yarn, both the mass at room temperature and the mass in the desiccator, the mean water vapour permeability value was calculated according to the equation:

$$WVT = \frac{m_r}{S \cdot t} \qquad (4)$$

where WVT is water vapour permeability (g/m^{2}h), m_r – mass difference (g), S – area of the metal cover opening (m^2), t – time (h).

Abrasion resistance of fabrics with fancy yarn
Abrasion resistance is defined as the resistance of textile material to loss of weight due to a certain load on abrasion. It is a relative criterion for the wearability of textile products in their use. It measures as an assessment of damage to the appearance of worn textile material compared to the original one. Abrasion resistance is influenced by the load of textile material, the time, the number of turns and the method of abrasion resistance, which can be one-way, circular or multi-directional [12, 14].
Method of work: abrasion resistance of fabrics with fancy yarn was measured according to SS-EN ISO 12947-2; Textiles – Determination of the abrasion resistance of fabrics by the Martindale method – Part 2: Determination of specimen breakdown [25]. Measurement was performed on a device called Martindale at 1000, 3000, 5000, 7000, 10000 and 12000 cycles. A round sample with a diameter of 2.9 cm was inserted into the cradle at a load of 12 kPa where it was circularly rubbed along a standard wool fabric installed on the device. Two samples of each yarn fabric with fancy yarn were made. The appearance of the analysed wear sample of the fancy yarn fabric was compared with standard photographs and estimated with the degree of peeling 5 to 1 (grade 5 means that peeling is not noticeable, while grade 1 means a strong peeling).

Dimensional stability in the washing of fabrics with fancy yarn
Dimensional stability in washing is defined as a dimensional change, which is expressed in the form of shrinkage or stretching during washing. During the washing process, the textile material is exposed to mechanical stress. It is measured as a change in the dimensions that occurs during the washing process. The dimensional stability of washing is influenced by the structural properties of textile material, which include the fabric construction, the yarn characteristics and the density of the thread. The type of washing program selected, the washing temperature, the time, the number of centrifuge plants and detergent [12] have an important influence on the dimensional change in washing.
Method of work: the dimensional stability of washing fabrics with fancy yarns was measured according to EN ISO 5077; Textiles – Determination of dimensional change in washing and drying [26]. The measurement was carried out in a classic household washing machine Gorenje WA 64153, a wash program with a temperature of 40°C, a centrifuge with 1300 rpm and the use of a liquid detergent. A square of 10×10 cm square was drawn inside a sample of 20×20 cm. After the wash, the size of the square was re-measured, and the dimensional change was determined in the warp and weft direction. Two measurements of each sample of the fabric with fancy yarn were made. From the measured values (final length B in cm) of the sample of the fabric with fancy yarn, the mean value of the dimensional change in washing, according to the equation, was calculated:

$$D_s = \frac{A - B}{A} \cdot 100 \qquad (5)$$

where D_s is dimensional stability (%), A – initial length (cm), B – final length (cm).

RESULTS WITH DISCUSSION

Permeability properties of fabrics with fancy yarn

Air permeability results of fabrics with fancy yarn
Figure 1 shows the results of air permeability of fabrics with fancy yarn.

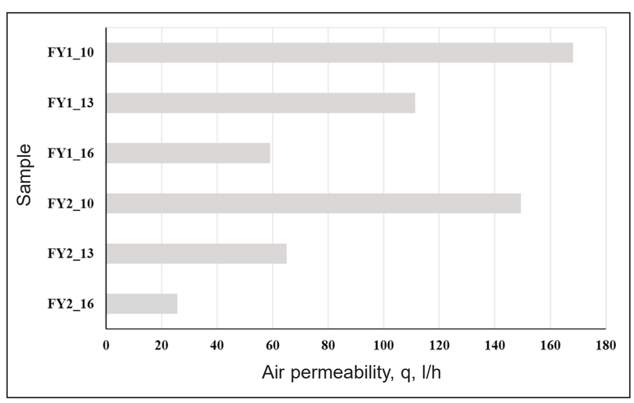

Fig. 1. The results of air permeability of analysed fabrics with fancy yarn

From the measured results of the air permeability of woven fabrics with fancy yarn, it is evident that the samples with the first analysed fancy yarn, labeled FY1_10, FY1_13 and FY1_16, made from 81% cotton and 19% viscose, express the highest air permeability. The reason is most likely to have a higher frequency of repetition of effects per meter of yarn (23%), namely a larger total diameter at the effective part (component1 – 1995 μm, component2 – 351 μm), but a smaller overall diameter on the base part (component1 – 757 μm, component2 – 343 μm). The FY2_10 sample has a lower air permeability (149.42 l/h) compared to the FY1_10 sample (168.16 l/h), the FY2_13 sample has a lower air permeability (65.07 l/h) compared to the FY1_13 sample (111.38 l/h) and the FY2_16 sample has a lower air permeability (25.7 l/h) than the FY1_16 (59.06 l/h) sample. The reason lies in the higher masses per unit area of the samples FY2_10, FY2_13 and FY2_16. The highest air permeability has the FY1_10 sample – 168.16 l/h, which has the smallest density (231.84 g/m^2) compared to other samples, the lowest density of the thread (warp – 24 threads/cm, weft – 13 threads/cm), maximal surface opening (8.74%) and minimal thickness (1.120 mm) between samples with yarn FY1 in weft. The smallest air permeability has a sample labeled FY2_16, which is only 25.7 l/h. The reasons are the highest mass (369.93 g/m^2), the maximal density of the thread (warp – 29 threads/cm, weft – 19 threads/cm) and the smallest openness of the surface (2.35%) among all samples.

Based on the measured results shown, it can be concluded that the structure of fancy yarn labeled FY1 with a smaller total diameter of the base part having a higher frequency of repetition is influenced by higher air permeability, a greater difference between the diameter of the components, both the base and the effective part and the higher frequency of repetition of the effects per meter of yarn, which consequently affect the greater openness of the surface. The samples with the first analysed fancy yarn in the weft, labeled FY1, made from 81% cotton and 19% viscose, express increased air permeability. The reason is most likely to have a higher frequency of repetition of effects per meter of yarn (23%). Higher openness of the surface influences higher air permeability or a greater number of empty interstices between the threads of the fabric. It is confirmed that the structural properties of textile material are affected by air permeability. Particularly important is the density of the threads of the fabric, since due to the increase, the air passage through the textile material is reduced. The reasons for the lowest air permeability of the sample labeled FY2 are the highest mass, the maximal density of the thread (warp – 29 threads/cm, weft – 19 threads/cm) and the smallest openness of the surface (2.35%) among all samples.

The results of water vapour permeability of woven fabrics with fancy yarn

Figure 2 shows the results of water vapour permeability of woven fabrics with fancy yarn.

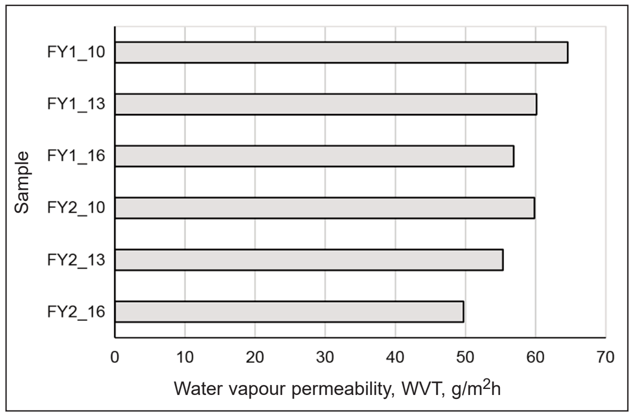

Fig. 2. Results of water vapour permeability of analysed fabrics with fancy yarn

From the calculated results of the water vapour permeability of woven fabrics with fancy yarn it is evident that in all three adjusted densities on the weaving machine (10 threads/cm, 13 threads/cm and 16 threads/cm) samples with the second analysed two-ply fancy yarn with the label FY2, made from a mixture of 67% viscose and 33% flax, express less water vapour permeability. The reason is probably the lower frequency of repetition of effects per meter of yarn (17%), namely a larger total diameter of the base part (component1 – 622 μm, component2 – 614 μm), but a smaller overall diameter of the effective part (component1 – 625 μm, component2 – 1415 μm). The FY1_10 sample has a higher water vapour permeability (64.58 g/m^{2}h), compared to the FY 2_10 sample (59.82 g/m^{2}h), the FY1_13 sample has a higher water vapour permeability (60.12 g/m^{2}h) in comparison with the FY2_13 sample (55.36 g/m^{2}h) and the FY1_16 sample has a higher water vapour permeability (56.85 g/m^{2}h) compared to the FY2_16 sample (49.7 g/m^{2}h). The minimal water vapour permeability expresses the FY2_16 sample, which has mass 369.9 g/m^{2}h, and a maximal thickness (0.992 mm) and a maximal thread density (warp – 29 threads/cm) in comparison with other samples with yarn FY2 in weft – 19 threads/cm) and minimal surface opening (2.35%) among all samples. The highest permeability of the water has a sample labeled FY1_10, which has mass 231.8 g/m^{2}h. The reasons for this are the fiber composition (81% cotton and 19% viscose), the smallest thickness (1.120 mm) between the samples with yarn FY1 in weft and the minimal density of threads (warp – 24 threads/cm, weft 13 – threads/cm) and openness of the surface (8.74%) among all samples.

Based on the calculated results shown, it can be concluded that the lower water vapour permeability is influenced by the structure of the fancy yarn labeled FY2 with a lower frequency of repetition of the effects per meter, having a smaller overall diameter and a smaller difference between the diameter of the components, both on the base and the effective part of the yarn, which influences on the openness of the surface increase. That results in a minor passage of water vapour through the textile material. It is confirmed that the water vapour permeability is influenced by the structural properties. In particular, the material composition of the textile material is important. It is known that viscose fibers have a higher hydrophilicity (12 to 14%) compared to cotton (7 to 11%), which makes them more absorbing, retaining and preventing its transition to the environment.

Abrasion resistance of fabrics with fancy yarn

Table 5 presents the results of the abrasion resistance of fabrics with fancy yarn.

From the results of the abrasion resistance of woven fabrics with fancy yarn, it is evident that the samples with the first analysed fancy yarn with the mark FY1, which is made from 81% cotton and 19% viscose, are more resistant to rubbing. The reason is most likely a larger number of turns, both on the base (88 T/20 cm) and the effective part (40 T/10 cm). In the case of FY1_10, FY 1_13, FY 1_16 and FY 2_16 with 12000 turns or rubbs did not break the thread, while in the case of the FY 2_10 and FY 2_13 samples, the basic threads in the effective part were completely broken. There was no breakage in the sample FY 2_16, most likely due to the maximal density of the thread (warp – 29 threads/cm, weft – 19 threads/cm). The highest abrasion resistance was measured with the FY 1_16 sample, which has an fancy yarn in a weft with a larger number of turns (basic part 88 T/20 cm, effective

Table 5

ABRASION RESISTANCE OF ANALYSED FABRICS WITH FANCY YARN

Sample	Comparable and estimated appearance of the sample at a given number of turns		
	1000	**3000**	**5000**
FY1_10	There is no difference in the appearance of the sample (peeling grade 5)	There is no difference in the appearance of the sample (peeling grade 5)	Light peeling, partially pulled fibers (peeling grade 4)
FY1_13	There is no difference in the appearance of the sample (peeling grade 5)	There is no difference in the appearance of the sample (peeling grade 5)	There is no difference in the appearance of the sample (peeling grade 5)
FY1_16	There is no difference in the appearance of the sample (peeling grade 5)	There is no difference in the appearance of the sample (peeling grade 5)	There is no difference in the appearance of the sample (peeling grade 5)
FY2_10	Light peeling, partially pulled fibers (peeling grade 4)	Moderately increased peeling and extracting fibers (peeling grade 3)	Moderately increased peeling and extracting fibers (peeling grade 3)
FY2_13	There is no difference in the appearance of the sample (peeling grade 5)	Light peeling, partially pulled fibers (peeling grade 4)	Light peeling, partially pulled fibers (peeling grade 4)
FY2_16	There is no difference in the appearance of the sample (peeling grade 5)	There is no difference in the appearance of the sample (peeling grade 5)	Light peeling, partially pulled fibers (peeling grade 4)
Sample	**Comparable and estimated appearance of the sample at a given number of turns**		
	7000	**10000**	**12000**
FY1_10	Light peeling, partially pulled fibers (peeling grade 4)	Moderately increased peeling and extracting fibers (peeling grade 3)	Very high peeling whithout brake (peeling grade 2)
FY1_13	Light peeling, partially pulled fibers (peeling grade 4)	Light peeling, partially pulled fibers (peeling grade 4)	Moderately increased peeling and extracting fibers (peeling grade 3)
FY1_16	There is no difference in the appearance of the sample (peeling grade 5)	Light peeling, partially pulled fibers (peeling grade 4)	Light peeling, partially pulled fibers (peeling grade 4)
FY2_10	Very high peeling whithout brake (peeling grade 2)	Very high peeling whithout brake (peeling grade 2)	Increased peeling. perfect deformation and thread breakage (peeling grade 1)
FY2_13	Moderately increased peeling and extracting fibers (peeling grade 3)	Moderately increased peeling and extracting fibers (peeling grade 3)	Very high peeling whithout brake (peeling grade 2)
FY2_16	Moderately increased peeling and extracting fibers (peeling grade 3)	Very high peeling whithout brake (peeling grade 2)	Very high peeling whithout brake (peeling grade 2)

Note: Peel grades: 5 – No difference; 4 – Slight difference and/or slight peeling; 3 – Moderate difference. Peeling of different size and density moderately the surface of the sample; 2 – Significant difference and/or pronounced peeling; 1 – Great difference and strong peeling.

part 40 T/10 cm), maximal thickness (1.174 mm) between all samples and maximal density yarn (warp – 28 threads/cm, weft – 18 threads/cm) between samples with yarn FY1 in the weft. The smallest abrasion resistance has a sample labeled FY 2_10. The reasons for this are the fiber composition (67% viscose and 33% flax), fancy yarn in a weft with a smaller number of turns (basic part 52 T/20 cm, effective part 10 T/10 cm) and minimal thickness (0.980 mm) of the sample.

On the basis of the comparable results shown, it can be concluded that the structure of the fancy yarn with a greater number of turns is affected by the greater resistance of the textile material, both on the base and the effective part, which influence the better twisting of the fibers into the core of the yarn. It is confirmed that the structural properties of textile material are affected by the abrasion resistance. In particular, the raw material composition is important. It is known that cotton fibers are well resistant to rubbing, compared to flax and viscose, which are less resistant.

Results of dimensional stability in the washing of fabrics with fancy yarn

Figure 3 shows the results of dimensional stability in the washing of fabrics with fancy yarn.

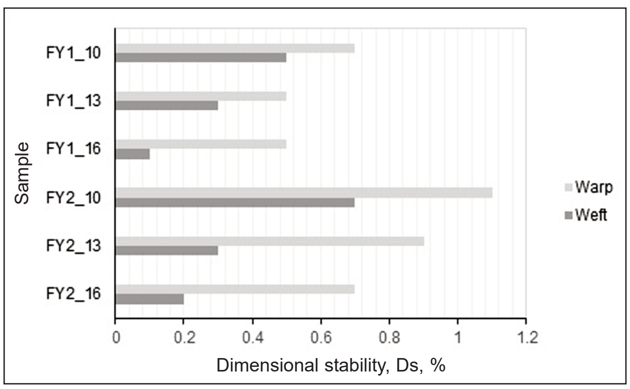

Fig. 3. Results of dimensional stability in the washing of analysed fabrics with fancy yarn

From the calculated results of dimensional stability in the washing of woven fabrics with fancy yarn, it is evident that the samples with the second analysed two-ply fancy with a mark FY2, made from 67% viscose and 19% flax, express increased shrinkage. The reason is probably in the smaller number of turns, both on the base (52 T/20 cm) and the effective part (10 T/10 cm) and the smaller percentage of the shrinkage (component 1: 0.8%, component2: 0.8%). The FY1_10 sample has a lower percentage of shrinkage (warp: 0.7%, weft: 0.5%) compared to the FY2_10 sample (warp: 1.1%, weft – 0.7%), the FY1_13 sample has a smaller percentage of shrinkage, warp: 0.5%, weft: 0.3%) compared to the FY2_13 sample (warp: 0.9%, weft: 0.3%) and the FY1_16 sample has a smaller percentage of shrinkage (warp: 0.5%, weft: 0.1) compared to the FY2_16 sample (warp: 0.7%, weft: 0.2%). There was no stretch for any sample of the analysed fabrics. All samples have a greater shrinkage in the warp direction (from 0.5% to 1.1%) than in the weft direction (from 0.1% to 0.7%). The worst dimensional stability in the washing has the FY2_10 sample, which shrunk by as much as 1.1% in the warp direction and by 0.7% in the weft direction, which has in comparison with other samples with yarn FY2 in the weft, the smallest mass (286.67 g/m^2), minimal thread density (warp – 25 threads/cm, weft – 14 threads/cm) and minimal thickness (0.980 mm) between all samples. The best dimensional stability with the washing has a sample labeled FY1_16, which shrunk by 0.5% in the warp direction and by 0.1% in the weft direction. The reasons are the raw material composition (81% cotton and 19% viscose), the highest mass (351.92 g/m^2), maximal density of the thread (warp – 28 threads/cm, weft – 18 threads/cm) of the samples FY1 in weft and maximal thickness (1.174 mm) between all samples.

On the basis of the calculated results, it can be concluded that the structure of the fancy yarn with a smaller percentage of the twist and a smaller number of turns, both the basic and the effective part, is influenced by the poorer dimensional stability in washing and consequently, larger shrinkage. It is confirmed that the dimensional stability of washing is influenced by the structural properties of the textile material. In particular, the raw material composition is important, as natural fibers, including cotton, linen and viscous, are shrunk in the washing process. For this reason, samples of an appropriately larger size were analysed. Smaller shrinkage in washing is also influenced by higher density of threads of fabric and thickness, despite the smaller fineness of the analysed fancy yarn.

CONCLUSIONS

Based on a study of the permeability properties, abrasion resistance and dimensional stability of fabrics with two-ply fancy yarn, it can be concluded that:

- Samples with the first analysed two-ply fancy yarn FY1, which is made from 81% cotton and 19% viscose, have higher air permeability than the samples with the second two-ply fancy yarn FY2, which is made from 67% viscose and 33% flax. It can be concluded that the structure of fancy yarn express important influence on increased air permeability. The most important parameters that have an important influence on air permeability increase are: a smaller total diameter of the base part, which is more often repeated, a higher frequency of repetition of the effects per meter of a yarn and a greater difference between the diameter of the components, both the basic and the effective part, creating more empty places between threads, affecting the increased passage of air through the textile material. It is confirmed that the greater air permeability of the textile material is also influenced by the lower density of the fabric and the consequent greater openness of the surface;

- Samples with a second analysed two-ply fancy yarn FY2, made from 67% viscose and 33% flax have lower water vapour permeability than the samples with the first two-ply fancy yarn FY1. It can be concluded that the lower vapour permeability is influenced by the structure of the fancy yarn with a lower frequency of repetition of the effects per meter of yarn having a smaller overall diameter and a smaller difference between the diameter of the components, both on the base and the effective part of the yarn, which reduces the openness of the surface, causes a slight passage of water vapour through the textile material. It has been confirmed that the higher permeability of the water vapour of the textile material is influenced by the fiber composition and the lower density of the threads of the fabric;
- Samples with the first analysed two-ply fancy yarn FY1, which is made from 81% cotton and 19% viscose, have higher abrasion resistance. It can be concluded that the structure of fancy yarn with a greater number of turns affects the greater abrasion resistance, both on the base and the effective part, which influence the better twisting of the fibers into the yarn, which makes the yarn harder to unfold. It has been confirmed that the strength of the textile material, the greater the thickness and the higher the density of the fabric are affected by the greater abrasion resistance;
- Samples with a second analysed two-ply fancy yarn FY2, which is made from 67% viscose and 33% flax have a worser dimensional stability when washing. It can be concluded that the structure of the fancy yarn with a smaller number of turns, both on the base and the effective part and the smaller percentages of the twist, is affected by the worser dimensional stability in washing or the greater shrinkage of the textile material. It is confirmed that the minor dimensional change in washing is influenced by the raw material composition of the textile material, the greater the thickness and the higher the density of the threads of the fabric.

Fancy yarns have become increasingly popular in the fashion industry lately. Due to the better mechanical properties and larger effects (higher difference between the base and effective part of the two-ply yarn), two-ply fancy yarn are mostly used, among other types of fancy yarns. New insights into the permeability properties of two-ply fancy yarns produced from the mixture cotton/viscose and viscose/flax blends thus make a new contribution to the development, production and responsiveness of fancy yarns in fabric during wearing the clothes from them.

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