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Properties of Yarns of Different Colours Sized by Standard and Pre-wetting Process

Abstract
This paper presents an investigation consisting of several stages of sample treatment and testing. The first stage was dyeing cotton yarns (with nominal counts of 20tex and 30tex) using reactive dyes to obtain yarns in six different colours. Differences in physical and mechanical properties between yarns of different colours were then investigated. In the second treatment stage all samples were sized using two processes: the standard sizing process and pre-wetting sizing process, with two different size concentrations, with the aim to investigate the influence of the sizing process on multi-coloured warp. Also the influence of dyeing on size bonding to the yarn were investigated, as well as on physical-mechanical properties of sized yarns, which are of paramount importance for the further process of making a woven fabric.

Key words: *sizing processes, dyed yarn, coloured yarn, cotton yarn, yarn properties.*

Introduction

The purpose of the sizing process is to improve the physical and mechanical parameters of the yarn in order to achieve a minimum number of breakages of warp threads in the weaving process at minimum cost. The goal of sizing is to keep the fibres in the yarn in the position where they were before sizing, with minimal yarn deformations during weaving. Today's achievements in all engineering branches enable the exceptional progress of the sizing processes to achieve a very high quality of sizing that meets the needs of today's modern weaving. However, sizing costs are still very high, despite the complete automation of the regulation and control of the most important sizing process parameters. Their reduction is possible by reducing the consumption of sizing agents and energy, as well as by the modernisation and development of machinery and technology, without any consequences on the quality of the sized yarn. Therefore two sizing processes were applied in this study in order to see possible differences in the properties of sized yarns obtained and consumption of all auxiliaries during sizing:

1. Standard sizing process (S)
2. Pre-wetting sizing process (P).

In order to fulfill all demands placed on the sized yarn, the most important thing is to optimise and maintain the size pick-up constant, which can be continuously measured and maintained at constant temperature and size concentration in the size box, automatic regulation of the squeezing force, sizing speed, as well as yarn moisture before and after sizing [1 - 4].

The complexity of the problem increases when sizing multi-coloured warp, where significant inequality in terms of size pick-up, yarn extension during the sizing process, and ultimately the mechanical properties of the yarn occur. The parameters of the yarn to be subjected to the sizing process have a great influence on those parameters, except the sizing condition. Those parameters are significantly changed by dyeing in comparison to the undyed yarn, and they differ depending on the colour of the yarn, taking account of the different chemical composition of reactive dyes. Dyes applied to the yarn have a significant effect on size absorption, and thus on changes in physical and mechanical properties of yarns. If the yarn structure is „more closed", with fewer interspaces between fibres (which depends on the yarn structure - spinning procedure) or with a larger number of twists, then it will have a lower absorption of dye and size. Also, if the yarn entering the sizing box is previously dyed, and moreover wet (pre-wetting sizing process), therefore the interspaces inside the yarn are partially saturated with dye and water. Such yarn will not have the same size absorption ability as the undyed yarn nor the one that enters the size box dry, meaning that all parameters the yarn has after dyeing and sizing greatly affect yarn properties [5 - 8]. Therefore the following was analysed in this study:

1. influence of dyeing with different chemical composition of reactive dyes (by which we obtain yarns of different colours) on physical-mechanical properties of the yarn
2. influence and differences of two sizing processes and size concentrations on dyed yarns.

Experimental

Yarn dyeing

For dyeing the samples used in this investigation, which were composed of 100% cotton yarns, vinylsulfone based reactive dyes were chosen for their very good features and good fastness properties. The reactive dye molecule contains a reactive group (whose type determines the level of dye molecule reactivity) that during the dyeing process chemically react with cellulose fibres under alkaline conditions (chemical bonding), where they become a part of the fibre rather than remain an independent chemical entity within the fibre. During these chemical reactions, covalent bonds are formed between carbon atoms (-C) from the reactive component of the dye molecule (vinylsulfone residue) and oxygen atoms from hydroxyl groups (-OH) of the polymer cellulose fibres (***Figure 1***). Because of the covalent bond strength, the reactive dyes applied to cellulose fibres provide very strong colour stability and washability [9, 10].

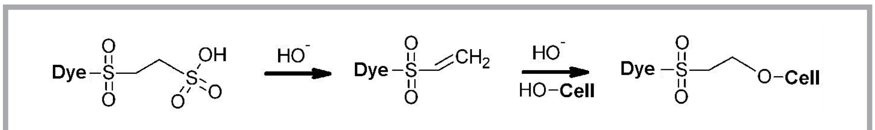

Figure 1. *Chemical reaction of vinylsulfone based reactive dye with cellulose fibre.*

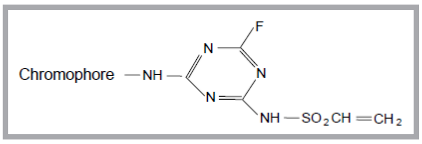

Figure 2. Chemical constitution of Cibacron FN dyes.

The dyes used to obtain a specific colour of the yarn are Cibacron FN dyes (***Figure 2***) of exceptional characteristics and with a high degree of fixation to cellulose (up to 84%), consisting of:

- vinylsulfone group - medium reactivity; dye-fibre bond stable to acids, chlorine and peroxide; high solubility
- fluorotriazine group - medium to high reactivity; dye-fibre bond stable to acids, chlorine and peroxide; high solubility - chromophore - highly sulfonated; very soluble; chlorine fast; good diffusion.

What makes the difference between the dyes used for dyeing samples is the reactive group and chromophore, whose structure defines the chemical constitution, size and planarity of the dye molecules. Those parameters affect the diffusion of dye molecules into the fibre, blocking functional groups of cellulose fibres. This leads to certain changes in fibre properties and yarn properties, which greatly affect the ability of wetting and thus the amount of size pick-up on the yarn. Besides the yarn properties, wetting ability is affected by the liquids used for wetting.

The concentration (c_d) of dyes used, which was calculated based on the weight of the fibre (owof), with Liquor ratio - LR = 20:1 (20 litres of dye bath is required for every kilogram of textile), is shown in ***Table 1***.

Table 1. *Dyes and concentrations (c_d) used to obtain a certain colour hue of the yarn.*

Colour of the yarn	Dyes (Cibacron FN)	c_d (%) owof calculated
Red (R)	c. Orange FN-R c. Red FN-R	1.20 2.34
Blue (B)	c. Yellow FN-2R c. Red FN-R c. Marine W-B	0.12 0.69 2.41
Yellow (Y)	c. Yellow F-4R c. Yellow FN-2R	0.04 0.02
Green (G)	c. Yellow FN-2R c. Red FN-R c. Brilliant blue FN-G	1.37 0.31 1.03
Black (N)	c. Schwarz W-HF	10.00

Before the dyeing process, to obtain yarns in red (R), blue (B), yellow (Y) and green (G) colour, the yarns were subjected to the bleaching process, while to obtain yarns in black (N) colour, the yarns were previously subjected to the boiling process. To obtain yarns in white (W) colour, the bleaching process was the only one implemented.

The dyeing process was carried out in two stages: In the first stage the yarn was dyed in a neutral dye solution by gradually adding salt. At this stage the fibre absorbed the dye evenly. The dye exhaustion of a specific dye is different (yellow is exhausted faster than blue or red) depending on the size and structure of a dye molecule. In the second stage, the bath is alkalised by adding sodium carbonate, allowing a chemical reaction between the fibres and dyes. Then together with exhaustion, dye fixation was carried out. To dye the yarns in red (R), blue (B), yellow (Y) and green (G) colour, Program 1 was used, which was carried out according to the process shown in ***Figure 3***.

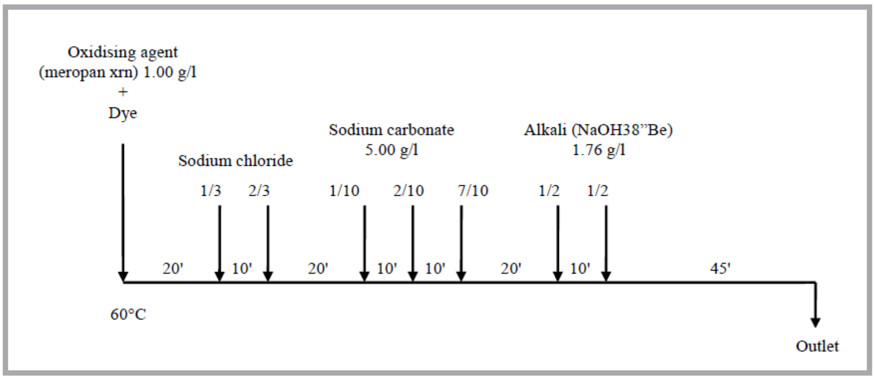

Figure 3. Dyeing process according to Program 1 (content of Sodium chloride depends on dye – 70.00 g/l to obtain R and B colours of yarns, 10 g/l to obtain Y colour of yarns, 55 g/l to obtain G colour of yarns).

To obtain a yarn in black (N) colour, the yarn was subjected to the dyeing process according to Program 2, shown in ***Figure 4***.

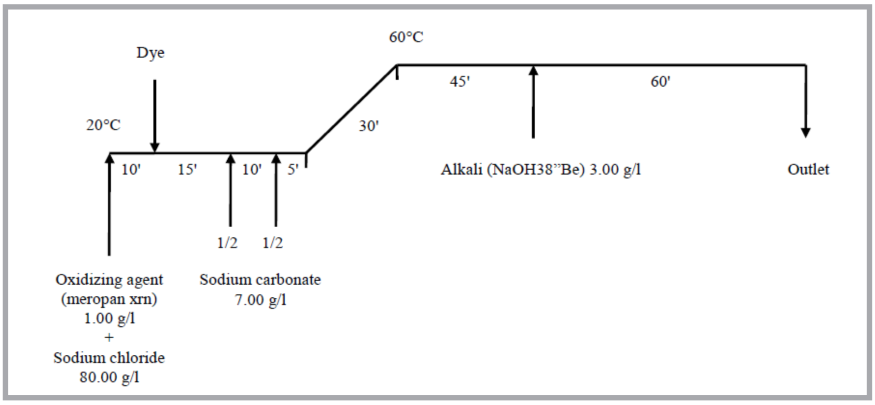

Figure 4. Dyeing process according to Program 2.

Sizing

The sizing processes used in this study were the standard sizing process and pre-wetting sizing process. Both were carried out on a laboratory sizing machine (***Figure 5***) constructed at the Faculty of Textile Technology, University of Zagreb, Croatia. The only difference in the structure of the sizing machine between the two processes is the pre-wetting box with hot water (in ***Figure 5*** marked with 3).

During the sizing process, two types of forces are to be overcome: the forces of surface tension (wetting) and those of diffusion. Penetration of the liquid (wetting) occurs in two phases:

1. penetration of the liquid into the capillary spaces between fibres of the yarn (during which two forces have to be overcome - the difference between the pressure of indoor air and the surrounding liquid, and tension forces of the interface between fibre and water)
2. penetration of liquids into the fibre, i.e. extrusion of air bubbles and filling those spaces with a liquid.

The importance of the pre-wetting box is in soaking the yarn in hot water (60 - 70 °C) before entering the size box, which enables the dissolution and removal of grease and other impurities and additives present in the raw yarn. Furthermore in the phase of pre-wetting, the yarn is wetted with water, i.e. interstitial spaces in the interior of the yarn are filled with water, and after squeezing the excess water the yarn remains wet and partially filled with water. As such, it enters the size box with much higher humidity than is the case with yarn in the standard sizing process, where it enters the size box dry. Therefore the contact of water retained in the yarn with the size leads to very rapid mutual bonding, allowing faster and easier penetration and diffusion of the size into the yarn. However, the size concentration in the interior of the yarn is lower than that in the size box because the water remained in the interior of the yarn after wetting diluted it. Therefore the greater part of the size remains on the surface of the yarn. When sizing dry yarn, the penetration of size into interstitial yarn spaces is not as rapid as in the case of wet yarn, and thus the inner part remains almost unfilled with size, while around or on its periphery a solid size coat is formed [11 - 15].

In the sizing process, warp tension is a very important parameter that must exist, which in turn causes extension (visible even at a minimum tension) and thus deformation, shown by changes in mechanical properties. During the pre-wetting sizing process, warp threads are between the pre-wetting box and size box in a wet state, making them even more sensitive to tension and thus more susceptible to extension. Other most important parameters in the sizing process on this laboratory sizing machine (***Figure 4***) can be regulated and maintained constant. It is possible to keep the water temperature in the pre-wetting box and size temperature in the size box constant by means of the built-in thermostat and heater, which heat water and size indirectly through the box walls. Drying sized yarn is preformed in contact, whereby the yarn runs over two heated cylinders. The speed of sizing can also be regulated and kept constant using a winder and optional speed regulator.

For the implementation of sizing processes, sizing agents from the company BEZEMA AG, Montlingen/Switzerland were used, whose features are shown in ***Table 2***.

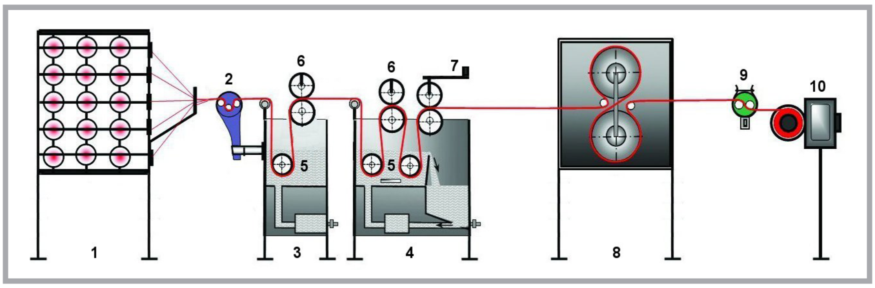

Figure 5. *Laboratory sizing machine: 1 - creel for cross wound bobbins, 2 - thread tension measuring device, 3 - pre-wetting box with hot water, 4 - size box, 5 - rollers for immersing yarn into size and water, 6 - rollers for size and water squeezing, 7 - regulation of the pressure of the last squeezing roller, 8 - contact dryer, 9 - contact measurement of moisture, 10 - winder of sized yarn.*

Table 2. *Properties of sizing agents.*

	TUBOFLEX PVA 80	TUBOWAX 24
Character	Sizing agent	Fat additive for sizing liquors
Chemical nature	Polyvinilachocol	Natural fats and waxes with a specific emulsifier system
Appearance	White granulates	Yellowish white granulate
pH-value	5 - 7	6 - 7 in a 10% solution
Application	4 - 10%	2 - 5 g/l
Temperature of application	75 - 85 °C	Min 65 °C in sizing 75 - 85 °C in overwaxing
Viscosity (Brookfield, sp2, at 85 °C, 100 r.p.m)	82.2 mPa	2.1 mPa

Table 3. *Sizing recipes and sizing conditions.*

Recipes	Recipe 1 (1)	Concentration – 7.5%	Water, l TUBOFLEX PVA 80, g/l TUBOWAX 24, g/l	1.0 100.0 3.0
	Recipe 2 (2)	Concentration – 5.0%	Water, l TUBOFLEX PVA 80, g/l TUBOWAX 24, g/l	1.0 70.0 2.1
Thread tension between the creel for cross wound bobbins and the pre-wetting box, cN				40
Temperature of water in the pre-wetting box, °C				65
Temperature of size in the size box, °C				75
Sizing speed, m/min				3
Pressure on the last pair of rollers for squeezing excess size, N/cm^2				19.1
Temperature on the cylinders of the contact dryer, °C				140
Output moisture, %				6

Size recipes were developed in accordance with the manufacturer's recommendation, type of yarn or fibre, and according to the needs and requirements of the sizing process. Sizing conditions were exactly defined and kept constant, shown in ***Table 3***.

Materials and test methods

Materials used for the whole research, from dyeing, sizing to testing, were 100% cotton ring spun yarns, with a nominal yarn count (Tt_n) of 20 tex and 30 tex, with certain characteristics mentioned in ***Table 4***.

Where: Tt_n - nominal yarn count in tex, Tt_s - actual yarn count in tex, U - yarn twist ni t.p.m, H - yarn hairiness in number of fibres longer than 1 mm protruding from the yarn surface, A - abrasion resistance in number of cycles, F - breaking force in cN, ε - elongation at break in %, $\bar{x}$ - mean, CV - coefficient of variation in %, δ – standard deviation in %.

Tests performed were those most important for the further technological process of weaving. To test samples before and after sizing, standardised methods were used. Thus the breaking force and elongation at break were tested according to ISO 2062 on a Statimat M, made by the company Textechno H. Stein GmbH & Co. KG, Germany. Yarn hairiness before and after sizing was tested on the basis of the registration of fibres protruding from the yarn structure, according to ASTM D 5674-01 on a Zweigle G 565, while the abrasion resistance was measured before

Table 4. Parameters of the unsized yarn tested.

Parameters		Values	
Tt_n, tex		20.00	30.00
Tt_s, tex		18.55	29.57
U, t.p.m	$\bar{x}$	913.04	707.44
	CV, %	5.20	5.93
	δ, %	47.51	41.92
H (number of protruding fibres)	$\bar{x}$	20428	19055
	CV, %	2.30	2.09
	δ, %	470.12	397.91
A (number of cycle)	$\bar{x}$	80.76	144.80
	CV, %	11.63	14.92
	δ, %	9.39	21.60
F, cN	$\bar{x}$	281.69	375.04
	CV, %	6.78	12.63
	δ, %	20.76	44.60
ε, %	$\bar{x}$	3.83	5.42
	CV, %	7.26	9.53
	δ, %	0.29	0.56

and after sizing on a Zweigle G 551. Yarn twists were tested on a MesdanLab Twist tester, according to ISO 17202 [16].

Determination of the size pick-up can be performed in several ways, but in this work the gravimetric method was used (4). The process of implementation of this method is as follows: before sizing, the samples were dried to the stage of moisture-free in an oven under prescribed conditions (105 ± 3 °C in a current of dry air – described in ISO 2060), after which they were weighed and a moisture-free mass of samples was obtained. Then the samples were returned to climatic conditions and sized. After sizing, the samples were again dried to the stage of moisture-free and weighed so that the amount of dry substance of the size pick-up could be calculated using the formula:

$$Sp = \frac{G_S(g) - G_U(g)}{G_U(g)} \cdot 100 \qquad (1)$$

Sp – amount of size pick-up in %,
G_S – moisture-free mass of sized yarn in g,
G_U – moisture-free mass of unsized yarn in g.

Due to the large number of different samples and treatments, and for ease of understanding, an explanation of marked samples is given in ***Table 5***.

Results and discussion

The results of changes in yarns count are shown in ***Figure 6***, where it can be clearly seen that by dyeing, the yarn mass per unit length is reduced, i.e. the yarn count increases, by an average of 4% for 20 tex dyed yarn, and 9% for 30 tex dyed yarn. The greater reduction (9%) in mass per unit length of 30 tex yarn can be explained by the larger number of fibres in the yarn cross-section and fewer twists than the 20 tex yarn, which makes the yarn structure less compact and therefore more susceptible to changes that occurred as a result of dyeing. Differences between the various colours of yarns are visible in both counts (20 tex and 30 tex), mostly with the same ratios. These deviations are not great, but they are still taken into account in further calculations. Generally the yarn count increase (for both yarn counts - 20 tex and 30 tex) can be explained with the dyeing process. Since the yarns were dyed in hank form in a relaxed state, and since the dyeing process is carried out under certain conditions (temperature and chemical agents), dirt, grease and short fibres of the yarn were washed out, resulting in a reduction in the mass per unit length of yarn, i.e. the yarn count increased, despite the addition of dye.

Table 5. Marks of the samples and their explanation.

Mark of treatment	Explanation of mark	Mark of sample	
		Tt_n 20tex	Tt_n 30tex
U	unsized yarn	20U	30U
S1	yarn sized with the standard sizing process and recipe 1	20S1	30S1
S2	yarn sized with the standard sizing process and recipe 2	20S2	30S2
P1	yarn sized with the pre-wet sizing process and recipe 1	20P1	30P1
P2	yarn sized with the pre-wet sizing process and recipe 2	20P2	30P2

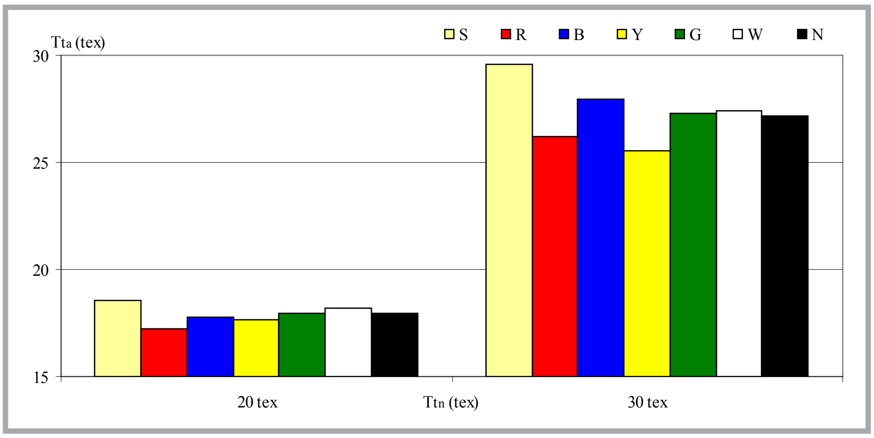

Figure 6. Diagram of changes in yarn count by dyeing; where: Tt_n - nominal linear density (yarn count) in tex, Tt_a - actual linear density (yarn count) in tex, S - undyed, R - red, B - blue, Y - yellow, G - green, W - white, N - black yarn.

Considering the size pick-up results (***Figure 7***), it is easy to notice similarities within the group in terms of yarn count. It can be determined that for yarns of the same count sized with different sizing treatments (S1, S2, P1, P2), there is a very similar relation between the size pick-up and certain colours. For example the 20 tex yarn saw the largest size pick-up for red (R) yarn, while the lowest was recorded for green (G) yarns. For other colours certain similarities can be established in order by the amount of size pick-up at the same size concentration (S1 ≈ P1, S2 ≈ P2), irrespective of the sizing process. 30 tex yarn had the largest amount of size pick-up for yellow (Y) yarn, then red (R) and blue (B) . Again it is interesting that there is a correlation with the treatment and same size concentrations, where S1 and P1 showed the smallest size pick-up for black yarns, while treatments S2 and P2 showed the smallest size pick-up for undyed yarns. Generally the results show very different values of the size pick-up of dyed yarns, which increase in some dyed yarns a few times compared to others, meaning that the specific dye molecule (its chemical constitution, size, planarity and its covalent bonding of the dye molecule reactive group with cellulose fibres) and dyeing process greatly influence the wettability of dyed yarns and absorption of size. The size pick-up for all yarns sized with the pre-wetting sizing process using both size concentrations was significantly lower than for yarns sized with the standard process, which was expected because one of the main advantages of the pre-wetting sizing process is great size saving, proven in this way. Besides this it can be concluded that by sizing with a lower size concentration, the amount of size pick-up on the yarn is lower.

Yarn tension is very important during the sizing process and it affects yarn extension, thus causing deformations seen as a change in tensile properties of the sized yarns. Laboratory analysis showed that these changes are visible even in the case of minimal tension. In the wet state, yarns are even more sensitive to tension, and therefore a greater deformation occurs during the pre-wetting sizing process. Tests conducted during the sizing confirmed this, the results of which are shown in ***Figure 8***. Yarn extension of all yarns is higher when they are sized with the pre-wetting sizing process (with both yarn counts - 20 tex and 30 tex, and both concentrations), the reason for which is the sizing procedure, where warp threads between the pre-wetting box and size box are wet, which makes them extremely sensitive to tension. In the standard sizing process the yarn enters the size box dry, and extension is reduced. Yarn extension is different for various colours of yarns, which represent a major problem in the industry, where in sizing multi-coloured warp, the amount of yarn used and that remaining is not equal, differing also in their properties. From the results it can be concluded that in all the yarns tested (regardless of the yarn count), the largest difference in extension between coloured yarn occurs during the implementation of the pre-wet sizing process with a higher size concentration (P1). Generally speaking, the largest extension occurs in red (R), which certainly affects their tensile properties. The results obtained show that yarns of the same count, sized with the same size concentration but with a different sizing process, have similar deviations between the various colours (for example, S2 ≈ P2; S1 ≈ P1).

The results of breaking properties (breaking force and elongation at break) of all yarns are shown in ***Figures 9*** and ***10***.

By dyeing, the yarn breaking force decreases for all colours of yarns in relation to undyed yarns. Unsized yarns record the largest drop in the breaking force of black (N) and then red (R) yarn, while the smallest drop was recorded for blue (B) and then yellow (Y) yarn. These differences in the breaking forces (***Figure 9***) of coloured yarn confirms and proves that certain dye as well as the dyeing processes affect yarn properties and thus the breaking force as well. This means that molecules of black dye and the dyeing process (program 2) mostly destroy the yarn, while in the case of yarn dyed with blue dye and program 1 the situation is reversed. As a result of detailed observation, it can be seen that the pronounced deviation and order of dyed yarns remains after all sizing treatments (for example, black yarns retains the lowest values of breaking force). Observing yarns by group, the breaking force increases mostly in yarns sized by S1 (almost identical in both yarn counts - by 52%), followed by group S2 (20 tex - 48%, 30 tex - 43%), and group P1 (20 tex - 47% 30 tex - 35%), while the lowest increase in breaking force was recorded in P2 (20 tex - 44%, 30 tex - 33%). From the

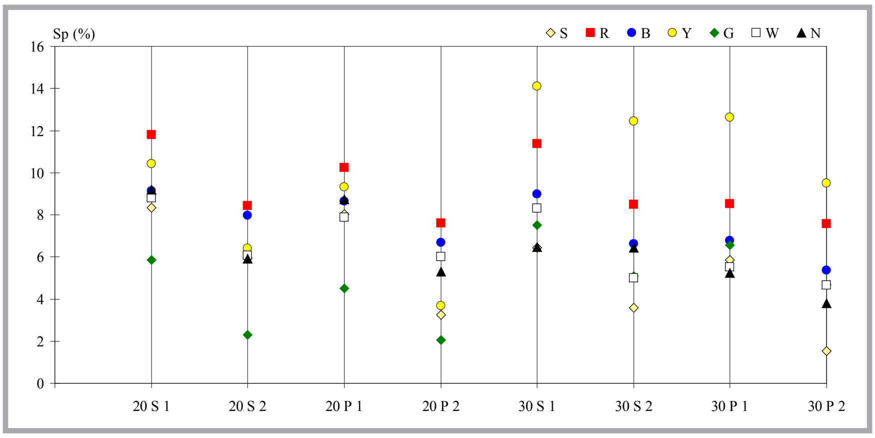

Figure 7. *Diagram of size pick-up (Sp in %) of the yarns.*

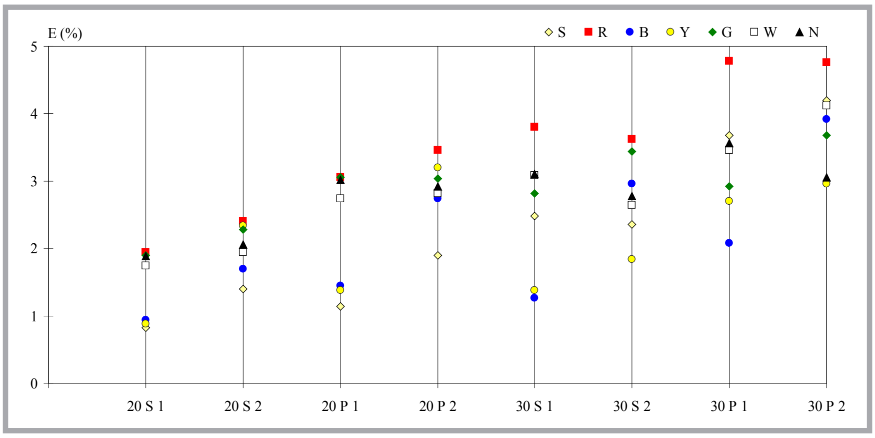

Figure 8. *Diagram of yarn extension (E in %) during the sizing processes.*

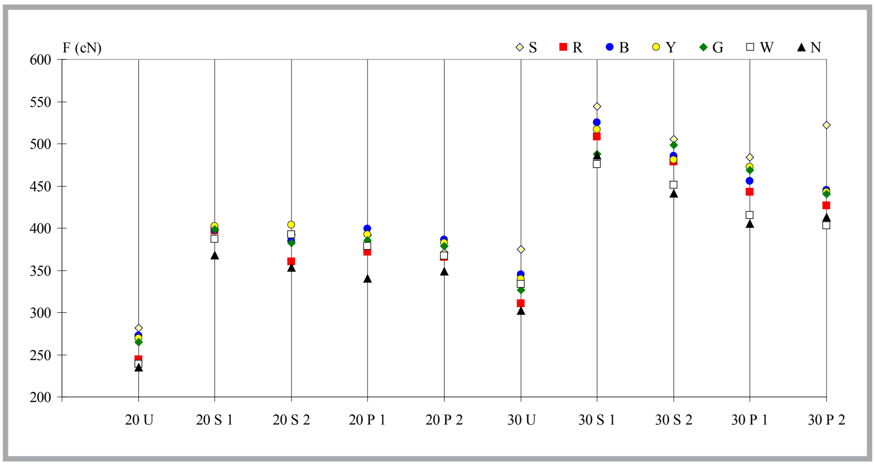

Figure 9. *Diagram of breaking force (F in cN) of the yarns.*

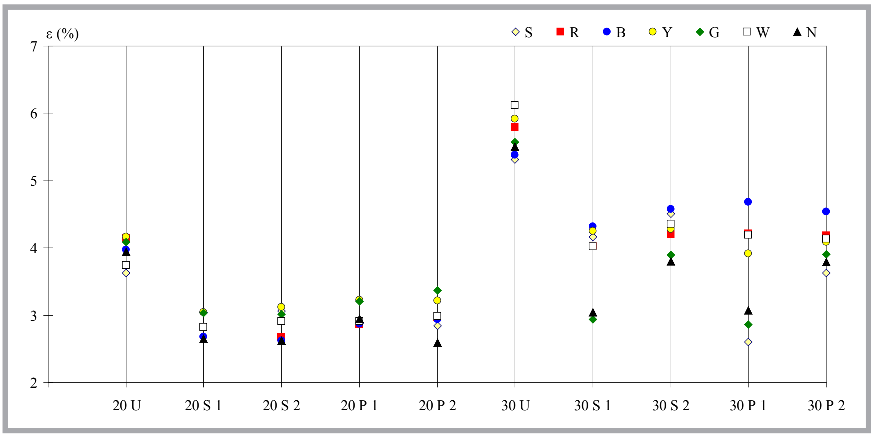

Figure 10. *Diagram of elongation at break (ε in %) of the yarns.*

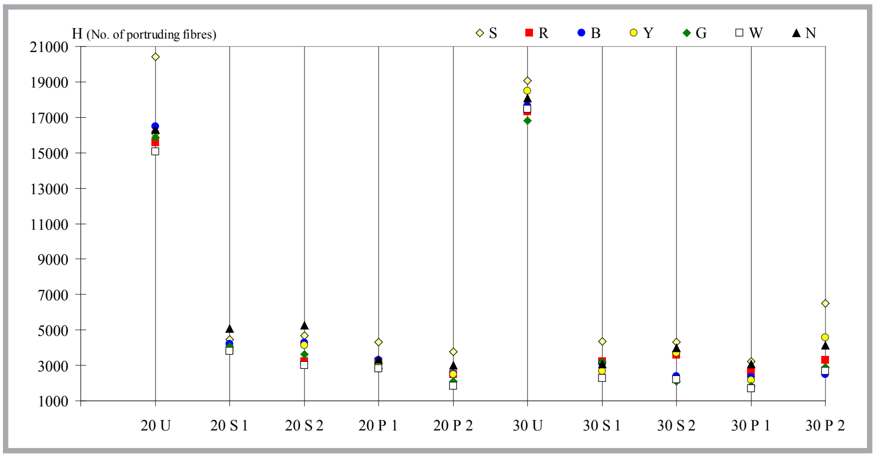

Figure 11. *Diagram of hairiness (H in no. of protruding fibres) of the yarns.*

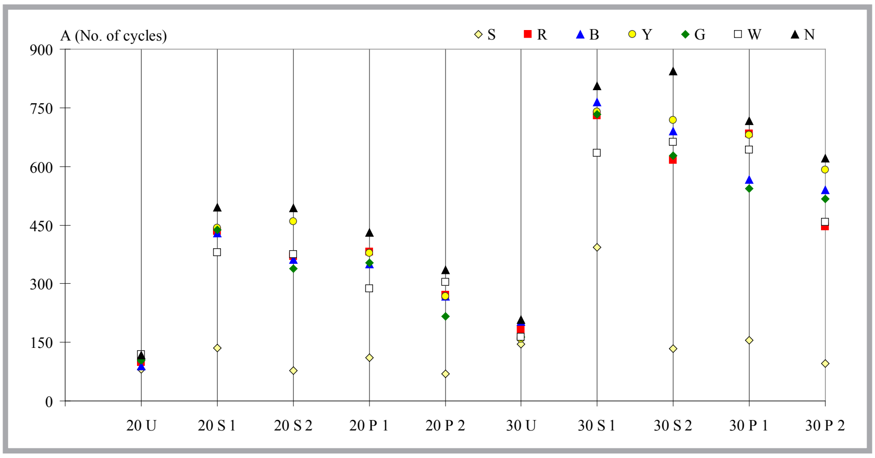

Figure 12. *Diagram of abrasion resistance (A in no. of cycle) of the yarns.*

above it can be concluded that the best results of the breaking force are obtained by yarns sized with the standard process, primarily with S1. Also those sized with the pre-wetting process do not differ drastically in the results obtained, only 5% on average for 20 tex yarns and 10% on average for 30 tex yarns, which proves that the pre-wetting sizing process with a small amount of size pick-up on the yarn and with a lower consumption of size agents, water and energy, gives almost equally good results, even when sizing with a lower size concentration.

By dyeing, the elongation at break (***Figure 10***) increases in relation to the undyed (S) yarns on average by 10%. The largest decline in the elongation at break for sized 20 tex yarns compared to unsized yarn was recorded for black (N) and then red (R) yarns, whereas the best results are shown by green (G) and yellow (Y) yarns. In the sizing of 30tex coloured yarns, blue (B) yarn shows the best results with all treatments. The minimum values of elongation at break are present in green (G) and black (N) yarns, while the pre-wet sizing process causes minimum values of the elongation at break for undyed (S) yarn. Some of the dyed yarns lose twice as much elongation at break than the others, which is especially pronounced in black (N) and green (G) yarns. According to the results obtained, it can be tentatively stated that by sizing, the elongation at break decreased, which represents a negative side of the sizing process. The pre-wetting sizing process shows certain advantages, where generally the elongation at break is somewhat higher, especially in dyed yarns, where the elongation at break increases compared to undyed yarns, while the elongation decreases in the standard sizing process. These indicators are of great importance for the subsequent weaving process, and can be associated with a lower size pick-up on yarns sized with the pre-wetting process, where the yarns did not become stiff as those sized with the standard process.

Hairiness is a very important feature in the weaving process, where due to high frictions (caused by the yarn passage through metal parts of the weaving machine), yarn breakage and, thus, faults in the fabric occur, resulting in a decrease in the quality of finished fabrics (***Figure 11***). Higher yarn hairiness also resulted in a greater friction between the yarns, caused by bonding the yarns with the size. The necessary separation of yarns after drying causes more damage and uneven removal of the size pick-up from the yarn surface, which can also adversely affect the weaving process and finished fabric quality. From the results, it can be concluded that the dyeing process reduces yarn hairiness without there being significant differences between various colours of the yarn, on average 28% for 20 tex yarns, and 8% for 30 tex yarns. Due to sizing, the reduction is much more pronounced, where the dyed yarns (due to the fact that the dyeing process itself smoothes protruding fibres) become increasingly smoother, with a very small number of protruding fibres, making them suitable for weaving. Less hairiness is present in all yarns sized with the pre-wetting process (an average of 80%) due to previous immersion in hot water and having been passed through rollers for water squeezing, as well as to the size distribution on the yarn, making it smoother and thus less susceptible to rubbing i.e. friction. White (W) 20tex yarns, even after sizing with all treatments, recorded the best results, i.e. the smallest number of protruding fibres. Regarding the results of yarn with the highest hairiness retained, there is a difference between the two sizing processes, where with the standard process in first place are black (N) yarns, and then undyed yarns, while with the pre-wet sizing process the opposite is the case. Undyed 30tex yarn, even after the implementation of all treatments, maintains the highest hairiness, with white (W) yarns also showing the lowest number of protruding fibres recorded.

Tests of abrasion resistance show very interesting results. The dyeing process increases the abrasion resistance (***Figure 12***) of dyed yarns in relation to undyed ones on average by 31% for 20 tex and 24% for 30 tex yarns, while the sizing process increases this difference between undyed and dyed yarns even more. Also the behaviour of undyed yarns sized with the pre-wetting process is very interesting, where the values are even lower than that of unsized undyed yarns. In this case, black (N) yarns show the best properties after almost all sizing treatments. Yarns sized by the standard process give better results, with an average increase of 285% (for S1) and 235% (for S2) for 20 tex yarns, and 290% (for S1) and 250% (for S2) for 30 tex yarn, compared to unsized yarns. By sizing with the pre-wetting process, yarn abrasion resistance is not as high as for yarns sized with the standard process. Here the average increase is 205% (for P1) and 140% (for P2) for 20tex yarns and 210% (for P1) and 160% (for P2) for 30 tex yarns. From these results it can be concluded that in general the standard sizing process "protects" yarns from abrasion better than the pre-wetting sizing process, in which case, the size is mostly retained on the yarn surface, forming a strong film that is harder to destroy and tear off, while on yarn sized with the pre-wetting process, the size is evenly distributed over the cross section of the yarn, providing a little less resistance to abrasion. It is also very significant that higher size concentrations do not guarantee a much higher abrasion resistance.

Conclusions

From the results obtained by this investigation it can be concluded that yarns of different colours obtained by the application of reactive dyes with different chemical compositions on cotton yarns give different values of the properties investigated, which means that the dye itself as well as the dying process greatly affect the yarn properties, which is very important when choosing a multi-coloured warp, concerning the sizing process and subsequent weaving process (extension of various yarn colours during sizing is uneven, which affects the uneven consumption of yarns and different properties that yarns have after sizing, which significantly influences the subsequent weaving process - representing a major problem in the industry). There are generally no excessive variations in the values of certain properties found between the two processes, while some properties (which are of paramount importance for the subsequent weaving process - elongation and hairiness) show better results for yarns (especially dyed) sized with the pre-wetting process (this is very important for the weaving process, where during shed formation yarns are subjected to large dynamic loads, which cause permanent yarn deformation), even with a lower size concentration. This is a very important indicator because in spite of a lower amount of size pick-up, the yarn achieves exceptional performance due to the size distribution, which is also very significant because the pre-wetting sizing process achieves great savings of sizing agents, water (when sizing and desizing) and energy, which contributes to environmental protection.

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