European Journal of Emerging Technology and Discoveries
ISSN (E): 2938-3617
Volume 2, Issue 9, September - 2024

TECHNOLOGICAL IMPROVEMENTS IN RAW SILK TREATMENT FOR ENHANCED WEAVING

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Abstract
This article presents the results of research work carried out at the Uzbek Research Institute of Natural Fibers in close cooperation with the Fergana Polytechnic Institute to improve the technology of preparing raw silk for the production of a new range of fine, elegant and spectacular silk fabrics. The purpose of this research was to create a new range of fine, spectacular silk fabrics from natural silk by improving the technology of preparing raw silk threads for weaving. The new range of fine, spectacular silk dress fabrics is produced from raw silk with a linear density of 2.33 tex. In this case, both the warp and weft threads from raw silk are imparted a certain twist in the S direction on the TKM-8-12 dovetailing and twisting machine. The article also presents the results of laboratory tests of both raw silk and twisted threads in the testing laboratory of the institute. Based on the results of the conducted research, appropriate conclusions were made and recommendations for their use were given.

Keywords: cocoons, natural silk, raw silk, linear density, unwinding, doubling, twisting, fixing, warping, weaving, assortment, fabric, warp threads, weft threads, thin, spectacular.

Introduction

Natural silk is one of the ancient and expensive types of textile raw materials. Various products for household and technical needs are made from natural silk. Currently, silk processing enterprises of the Republic of Uzbekistan mainly produce a national assortment of avro fabrics, a small amount of crepe, technical fabrics and fabrics of the “Gas” class from natural silk. This is explained by the fact that the cocoon-winding enterprises of the republic mainly produce raw silk with a linear density of 3.23 tex and a small amount of raw silk with a linear density of 2.33 and 4.65 tex [1], although according to the terms of the current state standard of the republic O'z DSt 3313:2018, raw silk in 9 assortments can be produced from silkworm cocoons grown in the republic, starting from the thinnest 1.56 tex to the thickest 16.60 tex [2].
There is a great demand for thin, delicate and effective fabrics made of natural silk among the peoples of the world, especially among the peoples of African and Middle Eastern countries,

however, these fabrics are not produced by the enterprises of our republic, because these fabrics were once produced by the enterprises of the republic in more than 100 articles [3]. For example, in the '80s-90s, only the Margilan Silk Factory produced more than 8 million running meters of crepe fabric in more than 100 articles. However, after the collapse of the USSR in 1991, the Margilan Silk Factory stopped producing these fabrics, although the demand for these fabrics was high and after some time the factory itself ceased its activities [1]. Therefore, taking into account the demand of the world's population for crepe fabrics, employees of the Uzbek Research Institute of Natural Fibers have developed various new assortments of crepe fabrics. Some assortments of these fabrics are protected by patents of the Republic of Uzbekistan [4-9] and are being introduced into production.
In addition to national assortments of fabrics, many assortments of silk fabrics are produced from natural silk, such as dress fabrics, “Gas”, “Excelsior”, linen, jacquard, pile, haberdashery and many other fabrics [3]. Some of these fabrics are produced from twisted silk (for example, a group of crepe fabrics), and some assortments are produced from untwisted silk (for example, “Gas”, “Excelsior”).
Natural silk before weaving goes through several technological transitions such as rewinding raw silk from skeins into bobbins, doubling and twisting, fixing the twist, warping, rewinding into weft spools, picking up the main threads, etc. The combination of these operations is called the preparation of raw silk for weaving and the quality of the manufactured product depends on the correctness of these operations. The processes of preparing natural silk for weaving have been studied by many scientists and specialists and many methods have been proposed to improve the technology of preparation. However, many of these proposals have not been implemented in production. Therefore, we have proposed a new method of preparing raw silk for the production of a new range of thin fabrics based on the "Gas" fabrics.

Purpose of the Study

This research work aims to improve the technology of preparing raw silk for the production of a new range of fine silk fabrics by imparting a certain amount of twist to the warp and weft threads on a ring twisting machine of the TKM-8-12 type.

Research Methods

Theoretical and experimental research methods were used in the work. The methodological basis of the research was the work of scientists in this field and methods of mathematical analysis. The processing of the results of experimental research was carried out by methods of mathematical statistics.

Main Part

Raw silk received by a textile enterprise undergoes several special preparatory processes depending on its further use. Currently, most silk fabrics are made from warp and weft threads prepared by raking and twisting several raw silk threads. For example, national assortment fabrics such as “Khan Atlas” are made from twisted warp and weft threads, and crepe fabrics such as Crepe De Chine are made from untwisted warp threads and weft threads with high twist. Thin silk fabrics such as “Gas” and “Excelsior” are made from untwisted raw silk threads with a linear density of 2.33 tex and in some cases from raw silk with a linear density of 3.23 tex.

Raw silk intended for the production of fine silk fabrics must have high quality in terms of linear density. It is known that raw silk is produced by joint unwinding of several cocoon threads, therefore the unevenness of raw silk depends on the unevenness of the cocoon threads, which largely depends on the coefficient of thinning of the cocoon threads. The coefficient of thinning of cocoon threads of foreign breeds is 1.4-1.6, and of local breeds 3.2-3.5 times. Based on this, for the production of fine silk fabrics, it is advisable to use raw silk produced from cocoons of foreign, for example, from the Chinese breed. In addition, the linear density of the cocoon thread of foreign (Chinese) breeds is 0.250-0.270 tex, while the linear density of the cocoon thread of the local breed is 0.350-0.420 tex.

Taking into account the above for the production of a new range of thin silk fabrics, raw silk of a linear density of 2.33 tex was produced from cocoons grown from Chinese grana. As a control option, cocoons grown from the local breed "Oltin vodiy 2" ("Golden Valley 2") were used. The cocoons were unwound on a cocoon-winding machine FY 502 made in China. Before unwinding the cocoons of the experimental and control options, studies were carried out to determine the technological indicators of the cocoons by single unwinding of cocoons on a laboratory machine LK system UzNIISHP. First, the calibre, average weight of cocoons, silkiness of the shell and other technological indicators were determined according to the methods of current standards. Based on the results of a single unwinding on the laboratory machine LK of the UzNIIShP system, the following were determined: linear density, metric number, continuously unwinding and total length of cocoon threads, specific consumption of cocoons and other indicators of cocoons of the experimental and control variants, the results of which are given in Table 1.

Table 1. Some technological indicators of cocoons of experimental and control variants

Item No.	Name of indicators	Research options	
		Experiment	Control
1	The average weight of one cocoon, g	0.529	0.586
2	The average weight of the shell of one cocoon, g	0.269	0.287
3	The average weight of one doll, g	0.260	0.299
4	Cocoon calibers, %: – small (14-15 mm) – medium (16-19 mm) – large (20-22 mm)	 8.55 89.50 1.95	 5.75 72.19 22.06
5	Linear density of cocoon thread, tex	0.255	0.363
6	The average silkiness of cocoons, %	51, 05	49.01
7	Continuously unwinding the length of the cocoon thread, m	1349	763
8	Total length of cocoon thread, m	1365	1100
9	Unwindability of cocoon shell, %	91.65	86.12
10	Raw silk yield, %	43.70	31.10
11	Specific consumption of cocoons, kg/kg	2.29	2.85

The analysis of the results presented in Table 1 shows that the technological parameters of the cocoons of the experimental variant significantly exceed the similar parameters of the control variant. From this follows the conclusion that when unwinding cocoons in raw silk of a linear

ISSN (E): 2938-3617
Volume 2, Issue 9, September - 2024

density of 2.33 tex of the experimental variant in a rose under the catcher it is necessary to keep 9 cocoons of which 50% are new and 50% are old cocoons, and when unwinding cocoons of the control variant in a rose under the catcher it is necessary to have 7 cocoons, of which new cocoons should make up 65-70%. In addition, during the studies, the coefficient of thinning of cocoon threads was determined, which amounted to 1.47 in the experimental and 2.89 in the control variant.

After that, the cocoons were sorted, as a result of which the defective cocoons were selected, which amounted to 7.6% in the experimental variant and 15.9% in the control variant. After sorting, the varietal cocoons were transferred to the cocoon-winding department of the experimental base of the institute, where the cocoons of both the experimental and control variants were unwound. The experimental unwinding of the cocoons was carried out on a cocoon-winding machine FY 502 made in China. Table 2 shows the technological parameters of unwinding the cocoons of the experimental and control variants on a cocoon-winding machine FY 502 made in China.

Table 2. Technological parameters for unwinding cocoons of experimental and control variants on the FY 502 cocoon winding machine

Item No.	Name of indicators	Unit of measurement	Research options	
			Experiment	Control
1	Linear density of raw silk	tex	2.33	2.33
2	Number of cocoons in a rose under a catcher	pcs.	9	7
3	Ratios of new and old cocoons under the catcher	pcs/pcs	4/5	5/2
4	Length of grafting	mm	120±12	120±12
5	Unwinding speed	m/min.	110	100
6	Temperature of water in the winding basin	°C	45	45
7	Air temperature in the drying cabinet	°C	60-65	60-65

The analysis of the data presented in Table 2 shows that the results of the above studies were taken into account when determining the technological parameters for unwinding the cocoons of the experimental and control variants. Unwinding of the cocoons of both the experimental and control variants was performed on a cocoon-winding machine FY 502 made in China. The unwinding process for both variants proceeded normally. Table 3 shows some technological and quantitative indicators of raw silk produced from cocoons of both the experimental and control variants.

Table 3. Some technological and quantitative indicators of raw silk produced from cocoons of the experimental and control variants

Item No.	Assortment of raw silk	Silk product yield, %						Unwindability of cocoon shell, %	Specific consumption of cocoons, kg/kg
		Raw silk	Sdir cocoon	Odonka shell	Total silk products	Doll	Soluble substances		
Experimental raw silk produced from the cocoons of the Chinese silkworm									
1	2.33tex	43.1	4.43	2.1	49.63	47.8	1.57	92.88	2.32
Raw silk of the control variant, produced from cocoons of the local grana									
2	2.33tex	34.4	6.78	5.9	47.08	48.2	4.72	84.76	2.91

The data presented in Table 3 show that the raw silk produced from the cocoons of the experimental variant has very good technological and quantitative indicators compared to the raw silk of the control variant. It should be noted here that when producing raw silk from the cocoons of the experimental variant, the yield of cocoon stripping, odonk shell, and soluble substances are reduced to a minimum. When producing raw silk from the cocoons of the control variant, i.e. from the cocoons of the local grana, good results were also obtained for these breeds. The raw silk produced from the cocoons of the experimental variant in the amount of 26.600 kg and the control variant in the amount of 7.860 kg were subjected to comprehensive laboratory tests according to the methods of the current state standard of the Republic of Uzbekistan O'zDSt 3313: 2018 at the testing laboratory of UzNIINV, the results of which are given in Table 4.

Table 4. Results of laboratory tests of raw silk produced from cocoons of experimental and control variants

Signs	Research options					
	Experimental - 2.33 tex			Control - 2.33 tex		
	Actual	Standard	Grade	Actual	Standard	Grade
Deviation from linear density, tex	0.11	0.13	4A	0.14	0.15	3A
Disagreement 1	135	150	4A	165	170	3A
Disagreement 2	-	10	4A	18	17	2A
Purity for major defects, %, not less than	98	97	4A	95	95	3A
Purity of minor defects, %, not less than	97	94	4A	90	92	2A
Worst purity, %, not less than	95	90	4A	88	87	3A
Maximum deviation, tex	0.28	0.35	4A	0.39	0.40	3A
Disagreement 3	0	0	4A	1	1	3A
Rewinding capacity, number of turns, no more than, pcs.	5	4	3A	9	10	2A
Relative breaking load, cN/tex	34.2	30 and more	4A	31.6	30 and more	4A
Relative elongation at break, %	20.5	18 and over	4A	19.2	18 and over	4A
Coherence of the carriage's movements	78	60 and more	4A	72	60 and more	4A
General grade			3A			2A

The analysis of the raw silk test results presented in Table 4 shows that the raw silk produced from the cocoons of the experimental variant has very good quality indicators. The raw silk of the experimental variant mainly meets the requirements of quality class 4A, only for one indicator does it correspond to quality class 3A. However, according to the terms of the current state standard O'zDSt 3313:2018, the raw silk of the experimental variant is assessed as quality class 3A, since according to the terms of the current standard, the assessment of raw silk is determined by the worst indicator.

After all laboratory tests were carried out, the raw silk of the experimental and control variants was transferred for further processing to the twisting department of the experimental base of the institute. First, the raw silk of both variants was subjected to external inspection, after which it was kept in climatic conditions where the air temperature was 22°C and the humidity was 65% for 24 hours. After that, a certain number of skeins of raw silk were emulsified by splashing wrapped in a napkin and left to age for 8-10 hours. When emulsifying raw silk of both the experimental and control variants, the following emulsion composition was used (per 100 kg of raw silk): 60% oleic soap - 2.4 kg; castor oil, or perfumery, or vaseline - 0.8 kg; surfactant in steam - 0.4 kg.

The raw silk produced from the experimental variant cocoons in the amount of 26.6 kg was rewound from skeins into 2-flange spools on the M-210-ShL rewinding machine at a speed of 120 m/min. The raw silk rewound onto 2-flange spools was twisted first on the TKM-8-12 cantilever-twisting machine, then on the KE-145-ShL floor-twisting machine. The purpose of imparting single threads of raw silk is to improve the quality indicators of raw silk, especially the breaking load and breaking elongation. However, it is necessary to take into account that the breaking characteristics of the threads increase up to the critical twist, after the critical twist the breaking characteristics begin to decrease. In addition, with an increase in twist, the diameter of the twisted thread increases, which affects the surface density of the produced fabric.

After researching the optimization of the twisting process, we established the optimal twist of a single thread of raw silk in the amount of 450 cr/m in the direction S (left twist), after which it is necessary to determine the twist of the thread. The twist of twisted threads of raw silk is determined in different ways, for example, according to the empirical formula proposed by S.A. Anuchin [10]:

$$\mathbf{U = 2,5\,K^2\,\sqrt[4]{n}\,T_0/10^7}$$

Where: $U -$ укрутка нити, % ;

$K -$ amount of twist, cr/m; number of thread additions, pcs.; $n -$

$T_0 -$ linear thread density, tex

After determining the twist of the thread, the linear density of the twisted thread of raw silk was determined using the formula:

$$\mathbf{T_{1од} = T_0/(1 - U/100)}$$

The calculations given using the above formulas showed that when imparting a twist to the threads of raw silk in the amount of 450 cr/m, the linear density of raw silk hardly changes, since the twist of the thread in this case is only 0.118%. Therefore, in further calculations, the linear density of twisted silk can be taken as 2.33 tex. Imparting a twist to the threads of raw silk of the experimental variant in the amount of 450 cr/m was performed on a twisting-floor machine.KE-145-ShL, which was carried out normally. After twisting, the raw silk threads were steamed in a vacuum-steaming unit KSZX-1.4-4 of Chinese manufacture, at a steam temperature of 70-80°C and operating pressure of 4.7 105 for 20 min. To fix the twist of the raw silk threads. After fixing the twist, the twisted raw silk threads were subjected to laboratory tests, the results of which are given in Table 5.

Table 5. Results of complex laboratory tests of twisted raw silk threads

Item No.	Name of indicators	Unit of measurement	Digital indicators	
			twisted	untwisted
1	Nominal linear density of raw silk	tex	2.33	2.33
2	Actual linear density of raw silk	tex	2.37	2.23
3	Deviation from the nominal linear density.	tex	+ 0.04	-0.10
4	Nominal twist	cr/m	450	-
5	Actual twist	cr/m	458	-
6	Deviation from nominal twist	cr/m	+8	-
7	Relative breaking load	SN/tex	38.31	32.25
8	Deviation compared to untwisted thread	%	+18.60	-
9	Relative elongation at break	%	23,23	20,20
10	Deviation compared to untwisted thread	%	+15,00	-
11	Connectivity, carriage strokes	pcs.	96	78
12	Deviation compared to untwisted thread	%	+23	-

The analysis of the data presented in Table 5 shows that twisted raw silk threads have very good quality indicators in comparison with untwisted raw silk threads. For example, the breaking load of twisted silk is 18.6% higher than that of untwisted raw silk threads, and the breaking elongation is 15% higher. The cohesion of twisted silk threads is 23% higher than that of untwisted silk threads. Improvement of these indicators ensures the normal flow of further technological processes.
After comprehensive laboratory tests, twisted raw silk threads were transferred to warping machines to prepare warp threads and to weft winding machines to prepare weft threads.

Conclusions and suggestions

1. Nowadays, silk fabrics of various assortments are produced from natural silk. In this case, natural silk threads in several folds in twisted form are used as warp and weft (aur fabrics) or in combined form, i.e. warp threads without twist and weft threads of high twist (crepe fabrics), and fabrics of the type “Excelsior”, “Gas” are produced from single threads of raw silk without twist.
2. Silk enterprises of the republic produce only “Gas” and “Excelsior” fabrics from thin fabrics. “Gas” fabrics are used to produce kerchiefs, braids and scarves, and “Excelsior” fabric is used for technical purposes. Silk enterprises do not produce thin silk fabrics for dresses, although they are in high demand in the countries of the Middle East and Africa.
3. A new range of fine silk fabrics is offered, where twisted threads of raw silk with a twist rate of 450 cr/m in the S direction are used as warp and weft threads. Twist messages allow increasing the breaking load by 18.6%, and breaking elongation by 15%. At the same time, the cohesion of twisted silk threads is 23% higher than that of untwisted silk threads.
4. The new range of thin silk fabrics will be produced based on silk fabrics "Gas", while the surface density of the fabric will be increased by 50-60%. The new range of thin silk fabrics is recommended for use in evening dresses and outfits.

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