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Production of Offset Paper on the Basis of Cotton Cellulose with Synthetic Fiber Waste

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Abstract

In the conditions of the "Toshkent qog'ozi" factory, samples of paper based on cotton cellulose and waste of synthetic PAN fibers of various thicknesses were obtained at a laboratory facility. The dependence of the physical and mechanical properties of experimental papers on the linear density of synthetic fibers is studied. When using synthetic fibers with a finer linear density, the paper forming process is improved.

Keywords: cotton cellulose, textile industry waste, natural silk waste, synthetic fiber waste, paper, mechanical strength, density

Introduction

By the beginning of the 21st century, the volume of world production of various types of paper exceeded 370 million tons, with its per capita consumption on average over 50 kg per year [1].

The volume of the world production of semi-finished products predicted by 2021 will require 1.5-1.7 billion m^3 of raw wood, or about 50% of the current global production of wood in developed forests [2]. The most intensive growth in consumption is observed in China, the USA, Japan, Germany, Canada, Finland, Sweden, the Republic of Korea, France, Italy, Russia, and for these countries is approximately 6% per year. China is a world leader not only in paper production, but also in the volume of production and import of paper and paper products [3].

The rapid pace of development, which is due to the continuously increasing demand for paper products, has a number of serious difficulties. Wood pulp is one of the most important raw materials in the paper industry. However, in the conditions of the Republic of Uzbekistan, wood pulp is a scarce raw material, there are no sufficient areas with coniferous and deciduous trees. Obtaining cellulose or pulp from wood is associated with significant water consumption [4-6].

Uzbekistan does not have sufficient wood reserves, which determines the relevance of the production of fibrous semi-finished products from non-wood plant raw materials in the paper industry. So far, imported cellulose and waste paper are used for the production of paper and cardboard in the Republic. But the high cost of imported wood pulp, and the tendency to deterioration in the quality of waste paper, indicates the need to search for new types of cellulose-containing raw materials. An important source of raw material for the production of cellulose is the use as an alternative to wood pulp, obtained from annual herbaceous and perennial plants. At the same time, the country possesses significant annually renewable reserves of cellulose-containing raw materials of local annual plants (cotton, uluk, rice and wheat straw, etc.) suitable for cellulose production [7].

It should be emphasized that the annual amount of annual cellulose-containing plants and their waste is about 1200 thousand tons (rice straw at least 300 thousand tons, wheat straw 350 thousand tons, cotton linters 120-150 thousand tons, cotton stalk 600-650 thousand tons) [8-9]. Two types of fibrous semi-finished products are obtained from wheat straw: coarse mass with a yield of up to 65-70%, which is used for the production of cardboard, corrugated and wrapping paper, fibrous boards, etc., as well as cellulose with a yield of 35-45%, which is bleached and unbleached types in composition with wood pulp are used for the production of various writing, printing and other types of high-quality paper. Usually, the composition of such paper includes up to 75-80% of straw pulp and 20-25% of softwood pulp [10].

At least 300 thousand tons of rice straw is accumulated annually in Uzbekistan, which is destroyed after harvesting rice and which is a cheap cellulose-containing raw material for obtaining paper. Cellulose from rice straw does not have satisfactory strength properties; however, it is characterized, like cellulose from buckwheat straw, by high absorption and sorption properties. The strength characteristics of cellulose from buckwheat and oat straw are significantly higher than cellulose from rice straw. In terms of a number of indicators, they meet the requirements for bleached sulphate pulp from hardwood, which makes it possible to recommend the obtained cellulose as a composition for the production of various types of paper [11, 13].

Annual cellulose-containing raw materials in the form of wheat, rice straw, cotton stalk, kenaf, etc., compared with cotton fiber, are characterized by a significant content of readily hydrolyzable polysaccharides (hemicelluloses) in the amount of 13-25%, which have a beneficial effect in the production of paper sheets and cardboard for technical purposes (wrapping paper, container, shoe and other cardboard). Refined cellulose (bleached) obtained from this raw material can be widely used in the development (instead of wood) of higher-quality types of paper (writing, notebook, etc.) [14].

Despite the presence of a significant raw material base, recently, researchers and technologists are intensively searching for new types of cellulose-containing raw materials for the production of cellulose and paper and paper products based on it. As a result of research by scientists of the Tashkent Institute of chemical technology, a new method of obtaining paper from local raw materials – Jerusalem artichoke-was introduced in the world practice.

Currently, there are extensive Jerusalem artichoke plantations in the Beruniy district of the Republic of Karakalpakstan and the Kibray district of the Tashkent region. From the tubers of Jerusalem artichoke, known as an earthen pear, a glucose-fructose syrup of a drug, inulin, is obtained for the treatment of diabetics. After using the tubers, the aerial part of Jerusalem artichoke (in the form of stems) remains, which has not been used, is burned. However, studies have shown that Jerusalem artichoke stalks contain about 50% cellulose [15]. From the cellulose obtained from Jerusalem artichoke, you can get paper and paper products. Physicochemical and mechanical studies of products based on Jerusalem artichoke cellulose have shown that it is a promising raw material for paper.

The search for alternative sources of paper raw materials is becoming more and more acute and cellulosic licorice waste turns out to be one of the most promising plants for this role. In the Republic of Uzbekistan, in the basin of the Amu Darya River, there grows one of the types of licorice - licorice naked. Ural licorice is widespread in the Eastern and southern regions of Kazakhstan, Kyrgyzstan, as well as in the southern steppe regions of Western and Eastern Siberia. Licorice is a perennial herb, the underground mass of which is incomparably greater than the mass of the stems. Over the years, the root system of licorice occupies large spaces: its rapidly growing shoots can stretch for tens of meters, throwing stems from their buds to the surface of the earth.

Licorice pulp contains a significant amount of lignin, which is a significant disadvantage resulting in a relatively low whiteness compared to cotton pulp. The main reason for the reversal of the whiteness of licorice cellulose and paper based on it is a change in the structure of lignin. At the same time, licorice cellulose contains a sufficient amount of extractive substances that cause a decrease in whiteness and its stability [16].

Cotton is the oldest cultivated plant. It was grown in India and China as early as three thousand years before our era. Nowadays, cotton is cultivated in the fields of more than fifty countries. This plant is especially widespread in India, the USA, China, Brazil and the countries of Central Asia. World cotton production is 18-20 million tons per year. In Uzbekistan, up to 4 million tons of cotton stalks are annually formed in cotton fields [17]. Cotton fibers are the strongest and purest among natural fibers, composed of more than 90% alpha cellulose. The natural length of fibers in a cotton box ranges from 10 to 60 mm with a width of 0.02 ... 0.04 mm.

Cotton linters contain (in mmol / g) 0.0040 aldehyde and 0.0020 carboxyl groups. In comparison with wood pulp, cotton linters have significant advantages: higher purity, higher whiteness, and less hemicelluloses [18-19]. Obtaining such types of pulp from local raw materials will reduce the volume of deliveries of more expensive wood pulp from countries near and far abroad, and save the monetary fund of the Republic. Improving the process of obtaining paper based on cotton cellulose from local raw materials is import and resource saving.

Experimental Method

In connection with the foregoing, intensive research in the field of pulp and paper production, in particular expanding the raw material base, the use of secondary and non-wood cellulosic materials in the manufacture of paper products.

Reference information on the use of non-wood fibers in the pulp and paper industry is presented in [20-21]. Non-wood fiber is increasingly used worldwide as a source of fiber for papermaking. Annual plants have been used since the early 1800s. In the study, the authors describe in detail the process of preparing non-wood raw materials in the production of paper products.

The technology of making paper on an industrial scale from cotton cellulose (CC) is not economically feasible. Adding waste from the textile and chemical industries to the pulp will solve the problem of efficient and rational use of raw materials, save expensive cotton cellulose, reduce the cost of paper, and significantly reduce the need for importing paper from outside.

As is known, the Republic of Uzbekistan annually produces more than 14 thousand tons of synthetic PAN-fiber "nitron", which is produced from a ternary copolymer (92.5% acrylonitrile, 6.0% methyl acrylate, 1.5% itaconic acid) by the wet rhodanide method in in the form of staple fiber and bundle. At the same time, 25% of the produced fibers are used in the national economy of the republic, the remaining 75% are exported [22].

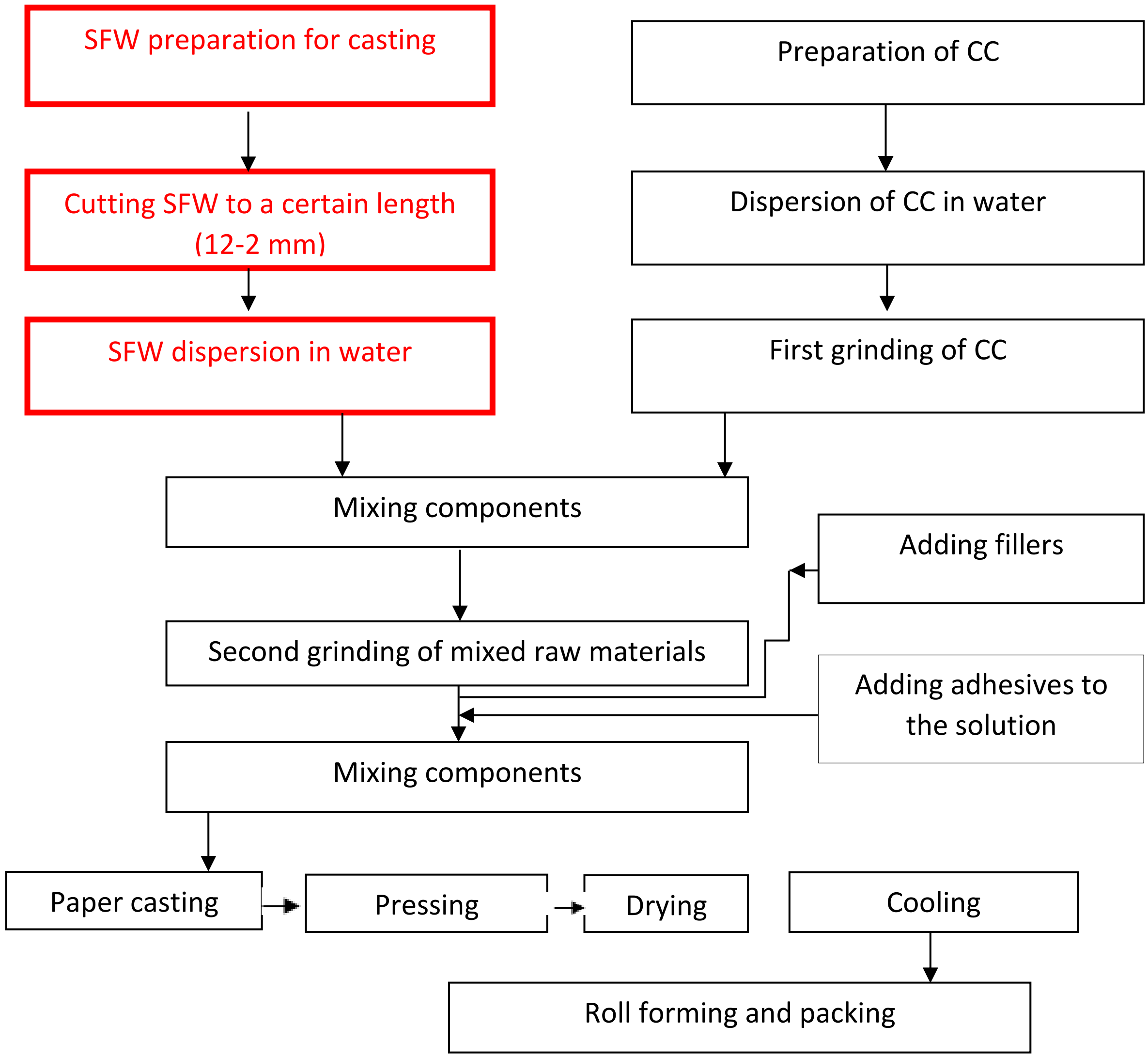

Figure: 1. Offset paper production technology based on cotton cellulose and synthetic fiber waste

Nitron is widely used in the production of textile fabrics, yarns, knitwear, used for the manufacture of upper knitwear, carpets, clothing and costume fabrics. In production, due to violations in the technological regulations, during the start - up and adjustment of equipment, as well as for other reasons, a certain amount of scrap – waste of synthetic fiber (WSF) accumulates. The use of waste from the cotton and textile industries will also help solve the important environmental problem of recycling this waste. Consequently, one of the directions of the economy of raw materials and environmental protection is to increase the level of use of secondary resources instead of primary raw materials.

In this scientific work, a complex of scientific- technical and technological works has been developed on creating new types of paper containing waste from the cotton and textile industries of Uzbekistan.

The technology for the production of paper with the addition of synthetic fibers does not fundamentally differ from the production of paper from plant fibers (Fig. 1). They are hydrophobic, do not swell in water and do not fibrillate when milled. Synthetic fibers have their own specific features: they consist in the need to cut fibers to a certain length, to find ways to obtain stable suspensions, and to select binders to ensure the bond between the fibers in the process of paper formation and finishing [23].

Synthetic fibers produced for the textile industry have a tortuosity that is necessary for processing them into yarn. The use of such fibers for papermaking is not possible. During mixing, connecting with each other, they form flakes, nodules, strands, which prevent the paper from uniform paper formation.

Therefore, for the manufacture of paper, it is necessary to use SFW, cut to a certain length. The strength of the manufactured paper depends significantly on the length of the used SFW. This research paper systematizes information about the influence of the structure of paper with chemical fiber additives on its physical and mechanical properties, as well as summarizes the results of research on their properties. When considering the influence of the shape of the fibers on the mechanical properties of paper, their tortuosity, determined by the number of turns per unit length of the fiber, should also be taken into account.

The mechanical properties of fibers are particularly affected by their density. As noted earlier, the density (or diameter) of the fiber has a significant effect on the stiffness of the fiber during bending due to the increase in the moment of inertia of the fiber relative to its neutral axis. The phenomenon of hardening of thin filamentous samples of various substances in comparison with bulk samples is well known.

OJSC “Navoiazot” produces Nitron cotton PAN-fibers with linear densities of 0.33 and 0.17. In this study, these fibers were used to determine the effect of the linear density of synthetic fibers and their ratios in the composition on the mechanical strength of the resulting composite paper [24]. It was assumed that the properties of papers with different densities can be determined from the characteristics of each type of fiber in proportion to its content in the mixture. Moreover, if the components differ slightly in properties and densities, the dependencies are expressed by a linear relationship. If there is a significant difference in the linear density of components, the rectilinear dependence is not maintained. The strength properties of experimental papers are determined, in which the mass ratios of CC and waste PAN fibers change, while the amount of fillers and sizing agents remains unchanged (table.1 and 2), the degree of cellulose grinding is 60 ^{o}SR, the mass of castings is ≈80±3 g / m^2.

The preparation of fibrous components slightly differs depending on the purpose of the offset paper. The SFW is subjected to grinding in the presence of water in batch grinding apparatus. When grinding in an aqueous medium, treated SFW are shortened to 2-12 mm. [22]. For synthetic fiber waste, you can choose the design and technical modes of the shredder-dispersant. Mixing of the components is carried out in a hydraulic diluent, paper casting−in the traditional way. Other technological processes-drying, pressing, cooling, calendering, roll forming and packaging do not differ from the traditional method approved by the technological regulations.

Production of prototypes of paper and quality assessment were carried out in the testing center for cellulose, paper, cardboard and other products, - by UzRITS TsBKI, Joint Stock Company "Toshkent qog'ozi" according to the approved technological regulations. The degree of grinding of cellulose fibers was 60 ° Shopper-Ringler. Samples were made in the usual way on a laboratory sheeter "Werkstoff Prüfmaschinen" (Germany). All samples with an area of 1 m^2 mass, ± 80 (± 3) g. When conducting research, a sizing agent was introduced into the paper pulp in an amount of up to 2% of the total paper pulp. When choosing a filler, we gave preference to kaolin, since it is one of the cheapest and most accessible fillers, on the other hand, it improves the physicochemical affinity of paper in relation to paint. The sizing agent of the experimental papers was rosin and polymer sizing agents. In accordance with the task, the composite composition of the paper was changed during the casting of samples [22].

Results and Discussion:

As can be seen from table 1, for castings containing SFW with a linear density of 0.17 Tex, in an amount of 15%, the strength decreases by 13%, with the introduction of 20% SFW, the strength decreases by 22%. With an increase in the content of synthetic fibers, the content of inter-fiber bonds between cellulose fibers decreases and, as a result, there is a decrease in breaking forces by half.

Table 1. Dependence of the mechanical properties of experimental papers on the content of OH, 0.17 Tex

№	Composition, %		Ash content %	Fracture, n	Breaking	
	CC	SFW			strength, H	length, L, м
1	100	0	3,7	41	44	3682
2	95	5	4,5	24	39	3590
3	90	10	4,5	19	36	3302
4	85	15	4,6	19	35	3181
5	80	20	4,7	19	25	2858
6	75	25	4,8	15	25	2736
7	70	30	5,1	17	24	2607
8	60	40	5,4	16	15	2339
9	50	50	5,5	14	16	1809
10	40	60	6,0	12	12	1754
11	30	70	6,5	11	11	919
12	20	80	6,6	10	10	447

Note: experience Error ±10%.

As can be seen from table 2, for castings containing 15% SFW with a linear density of 0.33 Tex, the strength decreases by 21%, with the introduction of 20% by 25%. In contrast to papers obtained with the addition of fibers from WWS with a linear density of 0.17 Tex, compositions containing fibers with a linear density of 0.33 Tex have lower strength indicators of breaking length. Therefore, the thinner the fiber, the greater the strength of the paper containing it.

Table 2. Dependence of the mechanical properties of experimental papers on the content of OH, 0.33 Tex

№	Composition, %		Ash content %	Fracture n	Breaking	
	CC	SFW			strength, H	length, L, м
1	100	0	3,7	41	44	3682
2	95	5	4,7	39	41	3504
3	90	10	4,7	39	29	3020
4	85	15	4,8	37	30	2900
5	80	20	4,9	36	25	2760
6	75	25	4,9	30	24	2500
7	70	30	5,2	26	23	2409
8	60	40	5,5	16	23	2129
9	50	50	5,8	16	15	1388
10	40	60	7,2	14	11	709
11	30	70	7,6	12	12	923
12	20	80	7,8	10	10	264

A comparative study of the paper-forming properties of waste with a linear density of 0.17 Tex and 0.33 Tex established the General nature of changes in the main properties of the fibrous material during the casting process. The paper break resistance index is one of the essential indicators that characterize the mechanical strength of paper. The ability of paper to withstand multiple folds is due to its porous structure. When bending, the outer side experiences tensile deformation, and the inner side experiences compression. With multiple bends, the number of breaks gradually increases, which leads to loss of strength and rupture [24].

With the introduction of 5% SFW with a linear density of 0.17 Tex into the mass of paper, the resistance to breakage (double kinks) decreases by 15%, and with the addition of 10% of the same fibers, it decreases by 18%. With the addition of 5% SFW 0.33 Tex, the resistance to fracture resistance (double kinks) is reduced by 34%, with the addition of 10% by 42%. The fracture resistance index depends to a large extent on the adhesion forces between the fibers. Apparently, SFW with a linear density of 0.17 Tex swells better in water and are moistened, which leads to a stronger mechanical adhesion of the fibers.

Conclusions

It was found that when using thinner (0.17 tex), short (2-12 mm) and uniform along the length of the SFW, the process of forming the paper is improved at the degree of grinding of the SFW 60 ^{O}SHR. In this case, a more uniform paper structure is formed with minimal distances between the macromolecules of CC and SFW, which leads to stronger mechanical adhesion, and, as a result, to obtain papers with better strength properties.

Fibers with a lower linear density form a denser paper structure with minimal distances between the functional groups of cellulose (- OH) and Nitron (−COOH). In an aqueous environment, hydrogen bonds are used to seal the structure of the paper sheet, which results in stronger mechanical adhesion, and as a result, to obtain papers with better strength properties.

The analysis shows the ways of optimal choice of the structure of the fibrous base for the manufacture of offset paper types. The paper with the addition of SFW showed a satisfactory breaking length. The use of waste PAN fibers is relevant for the Republic [105]. The use of waste from the textile and chemical industries, including synthetic fibers, partially solves the problem of a shortage of raw materials for paper production in the Republic of Uzbekistan.

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