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PAPER MANUFACTURE

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1 Claim. (Cl. 92—3)

My invention relates to the new and useful improvements in paper manufacturing and is directed more particularly to the manufacture of specialty papers having characteristics and properties which are not obtainable with the so-called papermaker fibers.

One of the principal objects of my invention is to provide strong paper-like material consisting of 100% of synthetic or man-made fibers without the use of any cellulosic or papermaker fibers. The fibers used according to this invention may be made of inorganic material, such as for instance, glass, quartz, aluminum silicates, or organic substances like nylon, cellulose acetate, etc. The major portion of the fibers employed shall have a thickness (diameter) of more than 2 microns, and preferably more than 5–10 microns. The organic or inorganic fibers, and glass fibers in particular, are characterized by smoothness, an inability to hydrate when beaten in water, and a lack of tendency to cling to one another when such a mixture is spread upon a continuously moving screen.

It was only recently possible to manufacture sufficiently strong sheet-like materials containing 100% of synthetic hydrophobic fibers which are arranged heterogeneously as in the case of ordinary paper made of organic fiber material. This could be done only through the employment of sub-micron fibers. The manufacture of 100% synthetic hydrophobic fiber paper, especially glass fiber paper, made of fibers with a diameter of, for instance, 5 microns or more, could not be achieved in a conventional way on paper machines. The employment of papermaker fibers such as rag and the like was, of course, known in making paper of such fibers, but the addition of this organic cellulosic material limited the use of such paper for many vital applications.

The addition of organic papermaker fibers to synthetic fibers impairs the wanted properties of the synthetic fiber paper as the same have the following inherited drawbacks:

1. Burnability
2. High water absorbency
3. Changeable behavior in different relative humidity of air
4. Shrinkage and stretchability
5. Poor electrical performance under moist conditions.

100% organic or inorganic fiber paper made of sub-micron fibers with a thickness below 1.5 microns for instance possesses, on the other hand, a number of unwanted features which make this paper unuseable for some applications.

Paper made of sub-micron fibers has a very low specific weight which is, in the average, somewhere around 0.2–0.25. The increase of the specific weight of the paper due to high pressure cannot be achieved if inorganic fibers, for instance glass, are employed, as every pressure tends to break the fibers on the crossing points and weakens the paper structure therefor materially.

100% sub-micron glass fiber paper, for instance, has a very high resin pick-up if impregnated. The resin to

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paper factor is 1 to 5 or more, while for many applications the ratio of, for instance, 1 to 3 is wanted.

It was found that the thinner the fibers in resin laminates and the smaller the weight percent of the fibers, the less impact strength and other vital strength requirements which are achieved. An inorganic fiber paper with a high amount of fibers of 5–10 microns or more thickness is, therefore, vitally wanted by the trade.

The thinner the fibers employed in the paper, the higher the fiber surface available. While this is, for air and liquid filter papers, a prerequisite, it is unwanted for other applications. The higher the fiber surface, the more surface moisture absorption is obtained. Thicker fibers used in the paper yield a smaller surface and so reduce the surface moisture absorption (unwanted for instance for electrical applications) up to, for instance, $\frac{1}{3}$ to $\frac{1}{10}$.

Sub-micron fibers are very expensive. This is easily conceivable as the reduction of the fiber diameter to $\frac{1}{2}$ increases, for instance, the fiber length already four times for the same fiber weight. In a given system, the same machine will therefore yield only $\frac{1}{4}$ of the weight production volume. The high price of paper made of, for instance, 0.5–1 micron fibers did prevent the application of such a paper for many uses.

The new method according to the invention allows therefore the manufacture of a glass fiber paper for raw material costs which are appreciably lower. The latter advantage, combined with the previous named one, opens up completely new fields for the application of synthetic or glass fiber paper altogether.

Unexpected results and results which could not have been foreseen were obtained in the manufacture of glass fiber and synthetic fiber paper using synthetic fibers without the necessity of adding any papermaker fibers according to this invention.

While it proved impossible to manufacture a sufficiently strong and thin paper made of 100% synthetic fibers, for instance glass fibers, with a thickness of, for instance, 10 microns, it was discovered that the addition of only for instance 1–2.5% in weight of fibers with a thickness of 0.2 to 0.75 micron to 97.5–99% fibers of 10 microns thickness did make it possible to obtain a glass fiber paper with properties heretofore unobtainable.

The following table will disclose that, for instance, the addition of only 1% sub-micron fibers of 0.2–0.75 micron thickness in combination with 99% fibers of 9 micron thickness increases the tensile strength of the paper approximately 700%. The addition of 2½ sub-micron fibers increases the strength of the glass fiber paper up to 1680%. In one series of tests performed under similar conditions, wherein the amount of sub-micron fibers used were changed in relation to the thicker glass fibers used, the following results were obtained:

Glass fibers 9 micron, percent	Glass fibers 0.6 micron average, percent	Weight, g./m. ²	Thickness, mil	Spec. Wgt.	Tensile Strength, g./in.
100	0	86	16	0.21	50
99	1.0	88	12	0.27	360–450
97.5	2.5	82	9.8	0.35	840
90	10	86	14	0.25	1,100
0	100	86			1,800

I established that many synthetic fibers can give similar results.

It is a prerequisite in papermaking on conventional paper machines that the strength of the wet sheet shall be sufficient to be carried over the paper machine. It was found that while a paper made of 100% 9–10 micron fibers has not enough wet strength, the addition of, for instance, 1–20% of sub-micron fibers increases the wet strength of the sheet so materially that such paper

can be manufactured on conventional paper machines. Under given working conditions, the wet strength of the sheet will have to be adjusted to the proper addition of sub-micron fibers to the stock. A paper with a weight of 100 g./m.² can be handled, for instance, with 1-2% sub-micron fibers, while a paper of 40-50 g./m.² did need the addition of 5-10% sub-micron fibers.

The following table reveals that the paper weight and the required strength of paper is a function of the amount of sub-micron fibers needed. The addition of 20% sub-micron fibers allows the manufacture of a paper with only 25 g./m.² if a tensile strength of 450 g./in. is sufficient. A paper of 75 g./m.² can be manufactured with only 2% sub-micron fibers with a similar tensile strength.

Fiber with φ 0.5 mi- cron, per- cent	Fiber with φ 9 micron, per- cent	Weight of paper, g./m. ²	Tensile Strength, g./in.
20	80	75	1,400
		60	1,180
		45	1,000
		30	650
		20	320
10	90	75	1,050
		60	880
		45	760
		30	500
5	95	75	750
		60	610
		45	470
		30	270
3	97	75	550
		60	430
		45	320
2	98	75	430
		60	340
0	100	120	80
		75	50

It has been found according to my invention that the thinner the sub-micron fibers, and the higher the number of sub-micron fibers per paper weight unit based on the same fiber lengths, and the better the fiber ratio between thin and thick fibers, the better will be the strength of the final paper and the vital properties requested of the same.

A paper made of 10 micron fibers contains, for instance, 2000 fibers per sq. cm. The same paper made of a mixture of 97.5 parts of 10 micron fibers (2000 fibers of 1 cm. length) and 2½ parts of 0.25 micron fibers (2000 fibers of 1 cm. length) consists of approximately 4000 singular fibers. In doubling the number of fibers per sq. unit, the points of fiber adhesion are increased materially. The retention of binder, filler, etc. is increased at the same time and aids in the effort to obtain the proper paper properties.

The relationship between long and thin fibers, or the fiber ratio in regard to the number of thick and thin fibers, governs the ultimate paper strength and also the strength of the wet sheet before it runs over the dryer section of the paper machine.

A mixture between 9 micron fibers and fibers of 0.5 micron shows, for instance, the following fiber ratio:

Parts fibers of 9 micron thickness	Parts fibers of 0.5 micron thickness	Relationship of number of thin fibers to thick fibers
80	20	4.5:1
90	10	2:1
95	5	1:1
98	2	0.36:1

The addition of sub-micron fibers to a glass fiber product consisting materially of 9-10 micron fibers yields further the following advantages:

The filler and color retention in the paper can be raised appreciably which makes the manufacture of an opaque paper.

The incorporation of sizing material becomes feasible with a high retention factor.

While a paper made of 100% 5-10 micron glass did show, in addition to a lack of strength, a very poor printability, the addition of 5-25% thin fibers did yield a paper with good printability. It was determined that by increasing amount of thin fibers, the printability is improved.

A fiber mixture according to my invention yields improved color properties in the paper as it makes the employment of pigment colors feasible.

Reference will be made to the table in Column 2 concerning the increase in the specific weight of the glass fiber paper due to the addition of sub-micron fibers for the employed paper making procedure. While the 100% 9 micron paper gives only a specific weight of 0.21, the specific weight of the paper containing 10% sub-micron fibers could be raised to 0.35. With filler addition, the same paper could be brought to a specific weight of 0.4 approaching the specific weight of cellulosic absorbent sheets which are used now for laminates, and the like. A glass fiber paper has, for this reason, the same resin pick-up as the conventional cellulosic paper material. This is wanted so as to obtain the ultimate properties of the final laminate.

It was found that 100% synthetic fibers, for instance glass, of for instance 10 micron thickness cannot be kept in the proper suspension necessary for the usual manufacturing conditions found in paper mills. The proper sheet forming to adjust the fiber stock was therefore not achievable with normal means.

The addition of only 1-2.5% of fibers of 0.2-0.5 micron thickness changes the stock characteristic of the thick fibers in a remarkable way. The fiber suspension becomes more uniform. The same does not settle or flocculate excessively and the proper sheet forming becomes feasible for this reason.

While a stock with 100% 9 micron fibers has a freeness of 9° SR, a paper containing 10% fibers of 0.5-0.7 micron thickness shows a freeness of 15° SR. A paper made of 100% fibers of 0.5-0.7 micron thickness has a freeness of 56 to 62° SR under similar conditions.

Paper made with a combination of thin and thick fibers according to the invention can be therefore manufactured with an appreciably higher machine speed than obtainable with sub-micron fibers alone as achieved so far.

By way of illustration, but not by way of limiting my invention, there are given the following specific examples:

Example I

100 lbs. of glass fibers with an average thickness of 9 microns and 2½ lbs. of glass fibers with an average thickness of 0.5 micron are beaten and uniformly distributed in a conventional papermaker beater in 5000 lbs. of water. To this mixture 20 lbs. of a latex emulsion with a solid content of approximately 38% and 2 lbs. of colloidal silica are added as a binder. The stock is handled in the conventional way and the latex is flocculated with the aid of alum or melamine plus urea resin.

This pulp mixture of glass and latex emulsion may be continuously fabricated into sheet form on a papermaking machine, the wet pulp being deposited upon a screen as a layer in the well-known manner whereby the glass fibers are arranged in heterogeneous relation without major orientation.

To improve the absorbency of the sheet the solution of a wetting agent can be spread on either the wet sheet or the dry sheet after or during the manufacturing of the paper.

I have found that paper so produced has a tensile strength of, for instance, 550 g./in. for a weight of 75

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g./m.² and a wet strength of 80-90% of the dry strength.
The paper stock similarly handled, but containing 10% of sub-micron fibers, yields a paper with a tensile strength of 1000 g./in.

I have determined that this paper can be impregnated with most conventional emulsions or resin solutions, either dissolved in water or in any solvents.

Example II

80 lbs. of organic synthetic fibers, for instance cellulose acetate or nylon with an average fiber diameter of 10-25 microns, are mixed with 20 lbs. of sub-micron fibers having an average diameter of 0.5 micron and are processed in the beater in the conventional manner.

This paper stock is formed to a fiber mat on the paper machine with or without the addition of binder resins, for instance melamine, urea, or glyoxal plus hydroxyethyl cellulose.

This paper is led, upon drying, through calender rolls which may be heated to a temperature approaching the softening point of the organic fibers used, and is pressed thereby.

A very strong organic synthetic fiber paper is obtained which can be manufactured with any strength, for instance, a tensile strength between 500 to 5000 g./in.

The sub-micron fibers used in this example can be glass or organic material with a melting or softening point materially lower than the thick fibers. Vinyon fibers with a softening point of 170° F. are feasible, for instance.

Having thus described my invention and the best manner of practicing the new process for forming this novel

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material without limiting myself to the order of steps of such process recited, or to the proportions of parts employed therein, or to the precise ingredients named therein, as it is evident that each of these ingredients has a considerable range of equivalents, and as it is also evident that the order and proportions of the process may be carried without departing from its scope and purposes what it is desired to claim and secure by Letters Patent of the United States is:

A paper product formed from a mixture of 5000 pounds of water including 100 pounds of glass fibers averaging 9 microns in thickness and 2½ pounds of glass fibers averaging 0.5 micron in thickness and 20 pounds of a latex emulsion and 2 pounds of colloidal silica.

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