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The Effect of Surface Sizing With Starch on Tensile & Tear

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THE EFFECT OF SURFACE SIZING WITH STARCH ON TENSILE & TEAR

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ABSTRACT

This survey of literature concerning surface sizing has been undertaken in an effort to compile in one paper the importance of surface sizing on strength properties, particularly tensile and tear.

The use of starch in the modification of surface characteristics of a writing medium may actually be older than the art of paper manufacture itself. A considerable amount of literature on surface sizing showing the effect on surface improvements of the paper sheet is available, but very little work has been undertaken to study the effect of surface sizing on tensile and tear.

Both their strength properties increased on surface sizing with low viscosity oxidized potato starch as compared to high viscosity starch, in which the latter case no significant effect was observed. High viscosity starch did not penetrate the sheet of paper, but rather stayed on the surface. This study showed that calendering after sizing operations should be reduced to a minimum to get improved tensile and tear. Otherwise, both these properties are appreciably reduced.

INTRODUCTION

According to Dard Hunter[1], the first surface sizing of paper with wheat flour was done about 700 AD; however, the sizing of papyrus sheets was carried out by the Egyptians and Romans as early as 2000 BC. It is important to realize how few papers are on the market today which can be manufactured without the use of some kind of sizing agent. Much of the earlier effort to rationalize the various effects of sizing behavior was emperical in that all the variables involved could not have been recognized or taken into account; even today such may be the case, but to a much lesser degree.

Starch can be used as a sizing agent either by "Internal sizing"; "Tub sizing" or "Surface sizing" method. This study is mainly concerned with surface sizing which is a process[2] in which the web of the paper is passed straight through the size press sizing solution being sprayed on the top role, while the bottom rubber roll carries sizing solution from the tub up to the nip where it is absorbed by the web. Starches for surface sizing are generally "converted" by one of several methods available for decreasing the high molecular weight of starch, such as oxidation; acid hydrolysis; enzyme action; etc. The technology of starches for surface sizing revolve about the problem of reducing the viscosity of starch sols. to an extent adequate for sheet penetration at appreciable concentrations and, at the same time, avoiding as far as possible, damage to the intrinsic adhesive quality and color of the starch.

The remaining technology remains in the hands of the paper manufacturer who can establish optimum sheet and application conditions to effect the best results.

According to Tucker[3] and his associates, surface sizing, has its primary purpose in the prevention of feathering in writing inks, the closing of the surface of the sheet, improvement of scuff resistance, and the laying of fuzz. Today, however, the term has a much broader connotation, i.e. the primary concern may not be a change in the rate of penetration of liquids, but a change in the strength, optical as well as structural properties of the sheet of paper. In this survey the effect of surface sizing with modified oxidized potato starch on tensile and tear is studied.

Starch was selected for this study because starch usage in the paper industry has increased over a number of years and there is every reason to believe that it will continue to do so. The most important economic factor in favor of starch is its low price. It has been estimated that over 140,000 tons of starch are used annually by the paper industry.

The term surface sizing, is, in certain respects, inappropriate because, in many instances the action of the surface sizing agents is not confined to the surface of the paper because it depends upon the type and the weight of the paper, the adhesive to be used, its viscosity, concentration, etc. The literature available on this subject has shown that it is possible to considerably increase the strength properties such as burst, fold, tensile etc., often without appreciable detriment to the tearing strength. It must be pointed out, however, that this survey showed a great diversity of opinion.

The six different experiments ran in the paper laboratory of Western Michigan University, showed that tear does increase appreciably

on surface sizing, but depending upon the original weight of the sheet, furnish and calendering operations.

THE PURPOSE OF SURFACE-SIZING WITH STARCH

Surface-sizing with starch is limited to the application of a film of starch at the wet calender stack, in the size press, or in a size tub. This excludes laminating adhesives, coating adhesives, and beater starch from consideration in this paper.

Many investigators[4] have studied carboxyl methyl cellulose, which is a derivative of cellulose, that CMC if applied at 150 degrees fahrenneit at the size press, about 2lbs/ton application brings about an increase in bursting strength of 5 to 20 percent. Eleanor F. Horsey[5] reports that strength properties are appreciably improved by using CMC as an internal sizing agent. Dow Chemical Co.[6] has also found that modified methyl cellulose (Methocel Hg) can be advantageously used for starch sizing formulation to improve strength properties. Casey[7] also states that modern papermills practice shows a definite trend toward moving starch from the beaters to the tub or size press where no white water losses are encountered, while physical properties are improved. It is possible that a slight but measurable decrease in strength by calender application. Although the above mentioned purposes have long been regarded as basic in surface application of starches, it has also been found and confined to this survey that the use of low viscosity starches in the size press often brings about high desirable side effects because it causes greater penetration of this starch sol. into the sheet with a subsequent improvement of tensile strength, tear, stretch and bursting strength.

Effect of surface-sizing with starch on physical properties

Usually there is enough penetration of sizing agents into the paper to increase the fiber bonding and the dependent properties, such as bursting, tensile, folding strength and the tear. Generally the strength properties are improved by using expensive fiber or by extensive beating or refining, but it should be emphasized here that this magnitude of strength in a sheet of paper can be secured by surface-sizing, as discussed further in this study.

Considerable literature available on this subject seems to indicate that the presence of starch adversely[8] affects tearing strength. The writer would like to stress here the surely, tear can be affected by overbeating the stock previous to sizing and then by carrying the calendering operations to its minimum after surface-sizing. But this study has indicated that, if it is possible to reduce the degree of calendering and also of beating, the tear figures are substantially improved, as can be seen in Table #1,2,3, and 4 respectively.

Millar[8] also reports that one mill, producing greaseproof paper had been striving to improve its tear figure on a 40 g/ sq.m. paper. Finally this mill reported to have improved tearing strength by 7 percent by using a special type of beater starch and freeness being dropped from 85 degrees S.R. to 80.

Surface-sizing with size press

Commercially paper is commonly surface-sized on the paper machine by means of a size press whereby the sizing agent is applied to both sides of the paper then passed through the press rolls which derive the size into the paper and remove the excess size from the surface

of the paper. The paper is in contact with the size for only a short period of time and the pick of sizes is relatively low.

There are two types of size presses used commercially,[9] vertical and horizontal. In the former case both the rolls are located one over the other whereas in the latter type of press, two rolls are side by side and the size is sprayed into the nip on both sides of the sheet, while the sheet travels downward through the sizing solution.

Recently, many mechanical improvements in the size press have been reported by Dixon[10] which have resulted in better performance. Among these are (1) top press helper drive, which prevents slippage of the top roll when highly lubricative materials are present in the size: (2) more accurate roll loading devices and expander rolls for wrinkles control.

Factors in size press operation

The most important factors in size press operations include the weight of the sheet, press roll construction, entry of the sheet to the press, release from the press, and finally the drying conditions after the press[11]. Depth of the pond and the nip pressure are the important operating factors which affect the amount of pick-up of the size. The rolls of a size press should be ground to a very smooth surface and kept in good condition at all times. There are many other factors which go beyond the discussion of this paper.

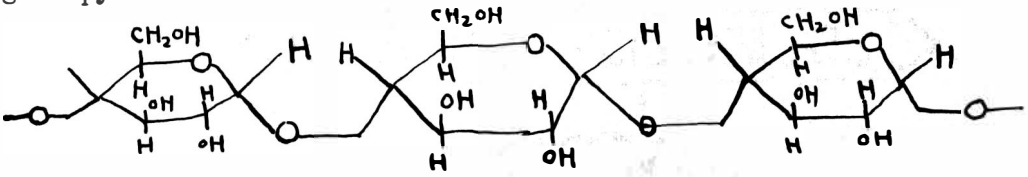
Sizing with starch in size press

The types of starches used in the size press varies all the way from solutions of unmodified potato and corn starch to solutions of oxidized or enzyme converted starch of very low viscosity. Modified

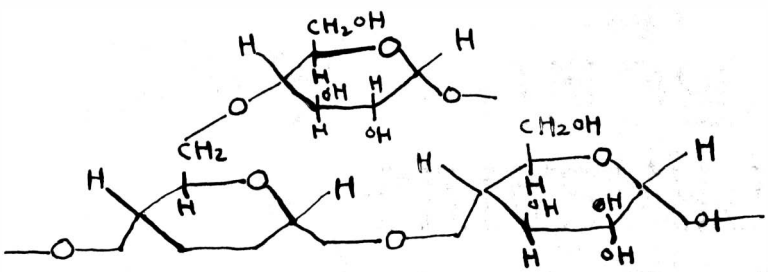
starches of medium viscosity are generally used, although it will depend upon the results desired. It is a well established fact that the higher the viscosity of the starch the greater the improvement in the strength of the paper per unit of starch applied. Generally high viscosity starches are used where scuff resistence is needed because such high viscosity starches tend to remain on the surface of the sheet of paper where they produce a tough durable surface. But it should be noted here that if maximum strength build-up is desired then low to medium viscosity of modified starches are used, as is discussed further in this paper.

Mechanism of starch penetration

Most varieties of starch contain two types of polymers which differ in molecular weight and in chemical structure. The linear polymer, amylose, consists of glucopyronose units joined through alpha-1, 4-glucosidic linkages and constitutes about 20 percent of the most of the starches; whereas the branched polymer, amylopectin, is made up of glucopyrunase units as shown below:



AMYLOSE CHAIN



AMYLO-PECTIN BRANCH

Starch is almost universally used for sizing because it provides a useful combination of film forming characteristics and serves as an excellent adhesive for fiber-to-fiber bonding and also for cementing loose surface fibers to the surface of the sheet. It first penetrates the sheet, whereby increasing the internal fiber-to-fiber bonding with the result towards increase in strength of a sheet as well as improving its surface characteristic, because a sort of close contact t ough film is formed on the surface.

LABORATORY EXPERIMENTAL PROGRAM

Summary

As discussed in the previous section which proceeds this report that two domestic commercial starches were selected for comparison, oxidized potato starch and corn starches, varying from low to high viscosity. For the sake ofcomparison, two different stocks were sized. It should be noted here that all the experimental work was done on a laboratory scale by using a hand driven horizontal press consisting of two rubber rolls. The pressure was applied by tightening the roll through a 14 revolution screw at the head of the press, which was always kept constant. A film of the sizing solution was sprayed on the nip of the rolls and then the sheet passed through it. After sizing, the sheets were dried at the room temperature without any tension and calendering was excluded except in two trials, for comparison with the non-calendered sheets.

It has been formed by this experimental survey that it is the calendering operation which reduces the tear of the sheet and the strength properties. Because the starch film formed on the surface as well as the internal, fiber-to-fiber bonding is weakened in the calendering operations. Other experimental results in which the sheets were not calendered showed quite an improvement towards tensile and tear, particularly with a heavy weight semi-bleached kraft stock as compared with light weight stock containing waste paper. All the efforts were made to carry out the work on a laboratory scale to the maximum accuracy. Since this work was done on a laboratory scale with a hand driven press, it might be possible that laboratory surface-sizing operational results might not correlate well with the results that can be obtained commercially.

Effect of surface sizing on tensile strength

It was determined in a tensile tester, which have the two clamps centered in the same plane parallel with the direction motion of the applied stress and so aligned that they hold the test specimen in one plane throughout the test without slippage. The test specimen being 200mm long and 15 mm wide. The instrument was loaded with appropriate rate of loading and at least ten strips cut in each principal direction of the paper tested in each case. The results are shown in Table,#1, 2,3, and 4 respectively.

During all the work throughout, the sheets, size 8½ by 11 inches, were sized with oxidized potato starch of low, medium and high viscosity. The starches were first heated to 85 degrees centigrade and then let stand to cool down til 60 degrees centigrade and then applied at the press for sizing. As shown in Table #1, it was found out that low viscosity starch can be used up to 10 percent solids. It should be noted here that in this study the penetration of starch was not uniform as can be seen in the seventh column of Table #1. With 2 percent of starch and of 0.680 lbs per-ream (25X38-500) the tensile increased by 1.5 points and with penetration to the amount of 1.820lbs/ream, in case of 10 percent solution; tensile increased by 2.35 points with appreciable increase of tear 11 points. The writer would like to point out here that in case of higher percentage sizing solution, it was observed that some of the sizing solution did not penetrate into the body of the sheet, but only stayed on the surface, as can be seen on Table #1 in the case of 10 percent starch, that is why the results came out to be so high as compared to low percent sizing solutions. To

avoid this, the next runs were carried on only with 2 and 4 percent sizing solutions. As shown in Table #2 and 3, it seems that corn starch gave better results than potato starch. As it can be seen that tensile strength increased only by 3 points maximum with potato starch, in both cases the penetration was almost the same. Tensile strength fell down considerably after calendering, showing thereby, that during the calendering operations the starch film as well as the cellulose chains are weakened. So a device should be developed such that calendering operations can be carried out without affecting the strength properties.

Table #4 shows that weight of the sheet is one of the factors which affects the results of surface-sizing. In this case the light weight stock was surface-sized under the same experimental conditions, but it is found that the tensile increase is not quite appreciable, only by 0.6 points with medium viscosity starches are preferable for surface-sizing to get better penetration and thereby get improved fiber-to-fiber bonding.

Effect of surface-sizing on tear

Tear which is defined as the tearing resistance determined as the average force in grams required to tear a single sheet of paper after the tear has been started. It was determined by using Elemendorf Tearing Tester, using 2.5 X 3inch long sheet specimens. The results are recorded as the force in grams required to tear a single sheet by using Tappi Factor. This property which generally depends upon the length of the fibers was found to improve by surface sizing because in this study the calendering was all together avoided.

As can be seen in Table #3, in two trials (i.e. with 2 and 4 percent low viscosity corn starch), the strength properties which increased considerably, decreased soon after calendering at 30 lbs. gauge pressure which clearly indicates that calendering operations did break the starch film and fiber-to-fiber bonding, thereby reducing the strength properties. Tear increased by 12.4 points with corn starch of medium viscosity (table #3) as compared to maximum increase of tear by 11 points with low viscosity starch (table #1).

All of this work seems to indicate that tensile strength and tear may be obtained by the application of low to medium viscosity sizing agents that results in penetration of starch beyond the surface of the sheet. In all of these operation the bonding power of the adhesive seemed to increase and can be maintained provided operations after surface-sizing could be improved.

Conclusion

This study work indicates that it is possible to improve the tensile strength and tear strength of a sheet of paper by the surface-sizing application of starch. There are basically two types of size presses in operation. Further work can be undertaken on both types of presses and study their effect. In the modifaction of starch for size press use, a number of important factors must be borne in mind. The viscosity of the starch and its temperature are among these. If the viscosity is too high, insufficient penetration will result and the starch film will stay only on the surface. On the other hand, too low a viscosity might cause undue penetration which might impair surface finish and pick. The trend towards a modified form of machine coating

by means of a size press seems to be becoming increasingly evident. One can now understand this in view of the obvious advantage attached to such an operation. It is an effective way in which a sheet whilst maintaining sheet strength properties as well as surface characteristic serve a dual purpose acheived by one operation.

TABLE #1 SHOWING THE RESULTS OF OXIDIZED LOW VISCOSITY STARCH

% Solids Starch used	TENSILE MD	TENSILE CD	INCREASE in Tensile	TEAR MD	TEAR CD	INCREASE in Tear	RETENTION OF STARCH Per Ream (25X38-500)lbs.
0	26.50	16.40	Points	129.2	138.0	----	----
2	29.30	16.60	1.5	130.0	144.0	0.4	0.680
4	30.10	16.80	2.0	130.0	148.0	5.4	0.900
6	30.30	17.00	2.2	136.0	148.2	8.5	1.000
8	30.80	16.70	2.3	135.0	150.2	9.0	1.060
10	30.90	16.70	2.35	139.0	150.4	11.1	1.820

TABLE #2 COMPARISON OF RESULTS OBTAINED FROM LOW, MEDIUM AND HIGH VISCOSITY OXIDIZED POTATO STARCH

% Solids Starch used	TENSILE MD	TENSILE CD	INCREASE in Tensile	TEAR MD	TEAR CD	INCREASE in Tear	RETENTION OF STARCH per Ream (25X38-500)lbs.
0	26.50	16.40	---	129.2	138.0	-----	-----
Low Viscosity							
2	29.30	16.60	1.5	130.0	144.0	0.4	0.780
4	30.10	16.80	2.0	130.0	148.0	5.4	0.998
Medium Viscosity							
2	30.00	17.00	1.0	130.0	146.0	4.4	0.988
4	31.10	17.40	3.0	132.0	144.0	4.4	1.995
High Viscosity							
2	27.00	16.50	0.3	132.0	148.0	6.4	1.615
4	26.60	16.50	0.1	133.0	150.0	3.9	2.090

TABLE #3 RESULTS OBTAINED FROM CORN STARCH

% solids Starch used	TENSILE MD	TENSILE CD	INCREASE in Tensile	TEAR MD	TEAR CD	INCREASE in Tear	RETENTION OF STARCH Per Ream (25X38-500)lbs.
0	26.50	16.40	---	129.2	138.0	---	----
Low Viscosity							
2	31.96	17.50	3.3	135.0	150.0	8.9	1.520
after calendering	28.00	15.00	0.5	110.0	135.0	-11.5	----
4	32.00	18.00	3.6	136.0	156.0	12.4	1.820
after calendering	25.80	14.80	-1.4	118.0	134.2	-7.5	----
Medium Viscosity							
2	28.00	18.00	1.6	136.0	150.0	9.4	1.615
4	29.00	17.50	1.8	134.0	148.0	7.4	1.750
High Viscosity							
2	26.90	16.20	0.1	134.0	140.0	3.4	1.615
4	27.00	16.20	0.2	130.0	140.0	1.4	1.820

TABLE #4 SHOWING THE RESULTS OFLOW, MEDIUM, & HIGH VISCOSITY OF OXIDIZED POTATO STARCH ON LIGHT WEIGHT STOCK (X)

% Solids Starch used	TENSILE MD	TENSILE CD	INCREASE in Tensile	TEAR MD	TEAR CD	INCREASE in Tear	RETENTION OF STARCH Per Ream (25¥38-500)lbs.
0	16.00	8.20	---	48.3	61.0	---	----
2 L.V.	16.45	8.40	0.33	60.0	66.0	8.3	1.235
2 M.V.	16.85	8.50	0.60	54.8	68.0	1.8	1.330
2 H.V.	16.20	8.00	0.10	52.6	64.0	3.7	0.950
4 L.V.	16.60	8.44	0.40	59.6	66.4	8.3	1.995
4 M.V.	16.40	8.00	0.10	51.8	63.6	3.1	1.125
4 H.V.	16.30	7.95	0.03	53.0	60.0	---	1.125

(¥) this furnish consists of waste paper by de-inking process

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