PULPS FOR PULP-REINFORCED PLASTICS

February 1945

No. R1472
(Report)

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
FOREST PRODUCTS LABORATORY
Madison, Wisconsin
In Cooperation with the University of Wisconsin

PULPS FOR PULP-REINFORCED PLASTICS[1]

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Abstract

Strong, tough, resin-filled, pulp-reinforced phenolic plastics containing 40 percent resin, based on the total oven-dry weight, were made at the Forest Products Laboratory from a variety of chemical pulps. The strength properties were not dependent on fiber length or pulp-sheet strength. Thus, black maple pulps whose fibers are only a quarter of the length of spruce fibers, were found to be suitable for the production of strong plastics. Contrary to what might be expected, the plastic flow and the required molding pressure of the various chemical pulp-resin combinations were not markedly influenced by fiber length.

Mechanical and semichemical pulps were found suitable for pulp plastics though, in general, these plastics were inferior in strength to those of the chemical pulps. In most of these plastics, however, the plastic flow of the pulp-resin combinations and the water resistance of the resultant plastics excelled those obtained with chemical pulps.

Modification of the pulp by mechanical and chemical treatment prior to filling with resin, and the addition of a noncellulosic constituent, glass fiber, were used to secure pulp plastics of altered characteristics.

Introduction

Wood pulp is being used to reinforce phenolic plastics, both in the form of paper and as resin-filled or impregnated pulp preforms. Another article[2] describes previous work by the Forest Products Laboratory with resin-filled pulp. A variety of pulps have now been tried and the results are presented here.

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[1] Presented at the meeting of the Technical Association of the Pulp & Paper Industry, New York City, February 19-22, 1945.

[2] Schwartz, S. L., Pew, J. C., and Meyer, H. R., "Pulp-reinforced Plastics," FPL Rept. No. R1461.

Materials

With the exception of the Mitscherlich-type sulfite pulp, all pulps used were made at the Laboratory. The Mitscherlich-type sulfite pulp was similar to that used in making aircraft grade laminated-paper plastics.

The properties of the pulps used in this study and other data are given in table 1. The spruce kraft pulps were specially prepared for high-strength laminated-paper plastics. The aspen and maple krafts were also specially prepared to give high-strength pulps. The sweetgum kraft had been made in other experimental work and was of only moderate strength. The soda, neutral sulfite, neutral sulfite semichemical, and groundwood pulps used in this study were either specially prepared or selected from pulps on hand. Pulping conditions were such that fiber degradation was at a minimum and the pulps were of good quality. The pulps used in plastics 209 and 210 were prepared from water-cooked chips. The wood chips were covered with water, digested for 10 minutes at 180° C. (354° F.) and reduced to pulp in a double-rotating disk mill. The total time of digestion was approximately 1 hour.

All chemical pulps were used in the unbeaten state; semichemical and groundwood pulps were used just as prepared without further processing. These pulps are further characterized in table 1, however, by the inclusion of sheet strengths of the pulps beaten to 550 Schopper-Riegler freeness as well as those in the unbeaten state.

Modified pulps for use in this study were obtained in several ways. The pulp flock used in plastic 165 was made by grinding spruce kraft pulp in a Wiley mill using a screen with 1/2 mm. diameter perforations. The mercerized pulp used in plastic 188 was obtained by treating spruce kraft pulp for 3 minutes with a 28-to-30 percent caustic-soda solution and then washing it free from the chemical. Neutral sulfite semichemical aspen pulp that was chlorinated with 16 percent chlorine and extracted with a 7 percent caustic-soda solution was used in plastic 146. In plastics 163 and 164, commercial glass fiber 1/2 inch in length was mixed with spruce kraft pulp.

The same commercial powdered phenolic resin was used in all experiments.

Equipment and Procedure

The equipment and method of converting the resin-bearing pulp to the plastic state has been described elsewhere.[2] The pulp, powdered phenolic resin, and zinc stearate (1 percent of the mixture) were suspended in water, at about 1 percent consistency. A wetting agent was used to aid in dispersing the powdered material. The stuff was formed into a mat 8-1/2 inches in diameter in a pressure forming apparatus. The amount of resin retained (resin content) was approximately 40 percent of the oven-dry weight of the mixture. The wet mat was dried in a forced-circulation oven at 35° to 40° C.

(95° to 104° F.) for 24 hours, conditioned at 24° C. (75° F.) and 50 percent relative humidity for at least 24 hours and molded between cauls at 160° C. (320° F.) for 13 minutes, using appropriate pressures determined by trial. All panels were removed from the press when still hot and allowed to cool in air at room temperature.

Testing of Plastics

Strength properties were determined on specimens taken from 1 to 4 nominal 1/8 inch thick panels of each pulp-type plastic. In general, the number and type of specimens taken from each panel were as follows: 2 tensile specimens, 2 compression specimens to determine the elastic properties, 4 compression specimens to determine ultimate strength, 5 toughness specimens, and 2 water absorption specimens. Tests, other than toughness, were made according to the methods outlined in "Federal Specifications for Plastics, Organic: General Specifications (Methods of tests) L-P-406, December 9, 1942." The toughness tests were made on the Forest Products Laboratory intermediate-capacity toughness-testing machine.

Results

The plastic properties and the properties of the pulps used are given in table 1. Strong and tough plastics were obtained not only with the long-fibered softwood, but with short-fibered hardwood pulps as well. Thus birch neutral-sulfite pulp (plastic 83), with approximately half the fiber length of spruce, gave a plastic with strengths about equal to those of the spruce kraft-pulp plastics 53 and 134. Black maple pulps, with only a quarter of the fiber length of the spruce pulps, also produced strong plastics. Contrary to what might be expected, plastic flow and the required molding pressure of the various pulp-resin combinations were not markedly influenced by the fiber length of the pulp employed. The short-fibered hardwood pulps, however, may felt better and may therefore be advantageous in the making of pulp-resin preforms by the suction process.

Pulp sheet strength is not important to plastic strength. Thus, spruce neutral sulfite, plastic 161, with an unbeaten pulp bursting strength of 1.03 points per pound per ream, did not give an appreciably stronger plastic than aspen soda pulp, plastic 204, which had an initial bursting strength of only 0.35 point per pound per ream.

Mechanical and semichemical pulps were also found suitable for pulp plastics. Groundwood pulps (plastics 86 and 144) gave plastics with somewhat lower tensile strength and decidedly lower toughness than the best of the chemical pulps. Even groundwood pulp plastics, however, were still greatly superior to wood-flour-filled plastics in these properties. In addition, the high-yield pulp-resin combinations flow well during molding and the resultant plastics had somewhat better water resistance than the chemical-pulp plastics. Plastics 209 and 210 made from water-cooked wood chips had only moderate tensile strength and toughness, but they had high water resistance and, especially with aspen, the flow during molding was exceptional. The semichemical pulps tended to give plastics with somewhat low toughness values, but otherwise were quite strong. The plastic flow of the spruce sulfite semichemical pulp (plastic 145) was very good. High-yield pulps, in general, present interesting possibilities and are being investigated.

Artificial shortening of spruce kraft fibers, as in the flock plastic 165, brought about a great reduction in the molding pressure required and an appreciable increase in flow as compared to that of the original pulp. Toughness and tensile strength of the plastic were reduced considerably, but were still relatively high. They greatly exceeded the toughness and tensile strength of wood-flour plastics. In view of the advantages of increased moldability and improved flow, such flocks may have merit. In order to limit the loss of strength occasioned by cutting the fiber, however, the method of felting the pulp-resin mixture from water suspension as described should be used rather than milling the pulp and resin together as is customarily done in commercial practice with cotton flock. Better strengths are obtainable by the aqueous method than by milling, since superior fiber formation results and further mechanical disintegration of the pulp by milling is avoided.

Properties of the plastic may be altered by the addition of other substances. A mixture of 20 percent or 50 percent of glass fiber with black spruce kraft pulp, as in plastics 163 and 164, respectively, improved the ultimate compressive strength of the product, but with the 50 percent glass-fiber mixture the ultimate tensile strength and toughness dropped considerably. Water absorption was decreased by the substitution of glass fiber for cellulosic material.

Properties of the plastic may also be modified by chemical treatment of the pulp. Ultimate compressive strength was raised by mercerizing the kraft fiber. Thus, in spite of the low resin content that tends to lower this property, plastic 188 was among the highest in ultimate compressive strength. Mercerization tends to produce high elongation in tension at rupture. The chlorinated and caustic-extracted neutral-sulfite semichemical-pulp plastic 146 and the black maple kraft plastic 205 likewise had rather high elongation.

Conclusion

It appears that strong, tough, pulp-reinforced phenolic plastics can be prepared from chemical wood pulp irrespective of the source and means of obtaining it provided the intrinsic fiber strength of the pulp is maintained. High-yield pulps, mechanical and semichemical, are suitable for pulp plastics and may prove advantageous for specific purposes. Specific properties of pulp plastics may be enhanced by modifying the pulp prior to combining with the resin or by incorporating a noncellulosic material in the pulp-resin mixture.

Table 1.--Certain properties of pulp-reinforced phenolic-resin plastics made from a variety of pulps.

Plastic No.	No. of panels tested[3]	Type	Pulp properties[1]: Cook, grinder run or shipment No.	Freeness (Schopper-Riegler)	Yield based on moisture-free wood	Bursting strength: Unbeaten	Bursting strength: At 550 freeness	Tearing strength: Unbeaten	Tearing strength: At 550 freeness	Tensile strength: Unbeaten	Tensile strength: At 550 freeness	Density: Unbeaten	Density: At 550 freeness	Cellulose content: Total	Cellulose content: Alpha	Lignin content	Total pentosan content	Plastic properties[2]: Resin content[4]	Molding pressure	Plastic flow[5] (diameter increase)	Water absorption in 24 hours[6]	Specific gravity	F.P.L.[7] toughness: Flatwise; 1/8-inch thickness	Tension: Ultimate strength	Tension: Proportional limit stress	Tension: Modulus of elasticity	Tension: Elongation[8]	Edgewise compression: Ultimate strength	Edgewise compression: Proportional limit stress	Edgewise compression: Modulus of elasticity	Edgewise compression: Yield point strength 0.2 percent offset
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)
				Cc.	Percent	Points per lb. per ream		Grams per lb. per ream		Lb. per sq. in.		Grams per cc.		Percent	Percent	Percent	Percent	Percent	Lb. per sq. in.	In. per 1,000 lb. per sq. in.	Percent		In.-lb. per in. width	Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.	Percent	Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.	Lb. per sq. in.
		Black spruce pulps																													
53	2	Kraft	2639-42	866	51	0.78	1.76	3.65	1.46	4,080	12,500	0.49	0.82	93	75	4.6	9.8	40	3,000	0.10	2.4	1.40	24	24,000	6,300	1,900	1.9	16,300	2,900	1,600	6,200
134	1	Kraft	1-2676	845	47	.57	1.76	3.20	1.53	2,690	12,500	.51	.83	93	75	3.8	9.7	40	2,750	.11	1.9	1.38	19	25,100	4,600	2,000	1.9	14,900	2,300	1,900	7,400
165	2	Kraft, ground to flock form[9]	1-2676	—	—	—	—	—	—	—	—	—	—	—	—	—	—	43	625	.20	1.8	1.37	14	12,700	4,000	1,100	2.2	15,600	1,700	1,100	4,800
163	2	Kraft, with 20 percent glass fiber[9]	1-2676	—	—	—	—	—	—	—	—	—	—	—	—	—	—	41	2,750	.10	1.6	1.43	19	22,900	6,200	2,000	1.7	18,500	—	—	—
164	2	Kraft, with 50 percent glass fiber[9]	1-2676	—	—	—	—	—	—	—	—	—	—	—	—	—	—	43	2,000	.17	1.2	1.52	11	15,300	4,400	1,600	1.4	20,900	—	—	—
188	3	Kraft, mercerized with caustic soda[9]	1-2676	—	—	—	—	—	—	—	—	—	—	—	—	—	—	33	2,400	.12	1.9	1.40	25	18,200	4,200	1,800	3.3	20,600	2,600	1,800	6,800
135	1	Sulfite, Mitscherlich type	8-1720	850	—	.69	1.00	1.57	.80	4,200	10,800	.60	.90	93	79	.9	5.6	40	2,750	.16	2.2	1.41	13	20,600	4,600	1,800	1.7	14,000	2,000	1,800	6,400
145	3	Sulfite, semichemical	5071-I	890	75	.22	.84	1.13	.65	660	5,600	.30	.57	69	55	20.8	7.6	41	1,000	.31	2.0	1.35	10	17,400	6,100	1,500	1.5	17,500	2,200	1,300	6,100
161	2	Neutral sulfite	5033-N	865	39	1.03	1.92	2.67	1.43	4,090	11,900	.49	.81	94	78	2.6	9.5	40	2,250	.13	2.1	1.40	21	22,900	6,700	1,700	2.0	17,000	2,500	1,600	6,200
209	1	Water cook	1	498	85	.40	—	1.34	—	2,230	—	.47	—	61	49	31.1	7.7	39	2,000	.25	1.2	1.36	10	14,500	6,000	1,400	1.3	18,100	3,000	1,300	7,600
86	4	Ground wood[10]	395	460	94	.25	—	.71	—	1,420	—	.39	—	60	43	28.0	12.3	40	1,300	.25	1.5	1.35	7	15,500	5,800	1,400	1.4	17,100	2,700	1,300	7,900
		Aspen pulps																													
206	3	Kraft	2689	825	—	.55	1.25	.98	.88	3,950	12,000	.60	.90	97	81	.9	—	41	2,500	.15	1.8	1.40	28	23,400	4,700	1,700	2.4	17,900	2,200	1,600	7,600
192	3	Neutral sulfite	5092-N	815	46	.50	1.17	.94	1.00	2,960	11,100	.54	.83	94	78	2.1	15.2	42	2,250	.18	1.8	1.38	27	24,000	4,800	1,800	2.1	14,000	2,600	1,600	6,800
150	3	Neutral sulfite, semichemical	5073-N	590	75	.68	.70	1.00	1.07	5,240	5,600	.65	.67	80	62	12.0	18.8	41	1,500	.23	1.8	1.37	15	19,100	5,300	1,500	2.3	18,400	2,000	1,300	5,900
146	3	Neutral sulfite, chlorinated and caustic extracted	5073-N	—	58	—	—	—	—	—	—	—	—	98	79	.5	19.7	39	1,000	.13	2.3	1.37	21	16,300	4,700	1,300	2.6	16,000	2,000	1,200	5,800
204	3	Soda	2687	810	50	.35	.91	.86	.87	2,440	9,800	.54	.87	96	85	1.3	16.4	41	2,500	.13	1.6	1.39	21	22,200	3,900	1,700	2.3	16,300	2,200	1,500	6,600
210	3	Water cook	2	597	80	.28	—	.61	—	1,760	—	.55	—	72	60	20.1	9.4	39	2,000	.41	1.2	1.36	12	17,200	4,200	1,500	1.8	17,300	2,400	1,300	6,400
144	3	Ground wood	418	462	94	.19	—	.48	—	920	—	.38	—	67	51	20.9	17.9	40	1,000	.19	1.6	1.34	9	15,800	5,600	1,300	1.6	17,300	2,300	1,100	6,600
		Sweetgum pulps																													
193	3	Kraft	2940	869	51	.31	.89	.96	.87	1,480	8,200	.48	.82	—	—	—	—	40	3,000	.10	1.9	1.39	19	17,700	4,100	1,500	1.9	16,500	2,800	1,400	5,700
149	3	Neutral sulfite, semichemical[11]	5083-N	895	82	.10	.50	.60	1.00	130	3,300	.24	.55	70	55	19.7	17.7	40	1,500	.24	1.9	1.36	12	17,500	6,200	1,400	1.8	18,600	1,600	1,300	5,600
		Black maple pulps																													
205	3	Kraft	2686	825	—	.42	1.28	.70	1.07	2,650	9,800	.54	.80	96	81	1.4	19.8	41	2,500	.10	1.7	1.38	20	19,900	3,800	1,900	2.7	17,200	2,300	1,300	6,000
191	3	Neutral sulfite	5093-N	840	54	.40	1.16	.79	1.08	1,970	8,600	.48	.77	93	76	3.5	16.0	42	2,000	.16	1.8	1.38	22	20,900	4,200	1,500	2.2	15,800	2,700	1,300	6,000
		Yellow birch pulp																													
83	2	Neutral sulfite	5036-N	880	45	.24	1.28	.95	1.00	950	10,400	.43	.81	95	76	3.0	19.7	39	3,000	.11	1.8	1.40	22	23,700	8,700	1,700	2.1	16,900	2,800	1,700	6,900
		Commercial phenolic plastics[12]																													
		Wood-flour filled																50	—	—	0.6	1.34	2	7,100	5,500	1,000	—	24,100	3,300	1,000	—
		Sisal filled																40	—	—	3.4	1.33	80	10,400	—	1,100	—	12,600	—	1,100	—
		Chopped-tire-cord filled																50	—	—	1.6	1.34	15	4,600	2,700	1,100	—	22,000	2,600	900	—
		Aircraft-grade paper-plastic (cross-laminated)																35	—	—	2.4	1.40	19	27,200	9,000	2,700	—	20,800	5,400	2,300	—

[1] Tests made according to Forest Products Laboratory standard testing methods for pulpwood, pulp, stuff, and paper.

[2] Properties were determined from specimens prepared, conditioned and tested in accordance with Federal Specification for Plastics, L-P-406, Dec. 9, 1942, unless otherwise noted. Machined edges were not otherwise finished prior to test. Compressive stress-strain properties were obtained by testing a 1- by 4-inch specimen as a laterally supported column. Ultimate compressive strength was obtained by testing specimens 1 inch wide by 1/2 inch long in pairs, 1 inch apart and parallel. Values represent the average for the indicated number of tests.

[3] Each panel furnished 2 tensile specimens, 4 compression specimens for ultimate strength determination, 2 compression specimens to determine elastic properties, 5 toughness specimens and 2 water-absorption specimens.

[4] Based on total oven-dry weight.

[5] This value is based on the expansion of the pulp mat during molding and is considered to be a rough measure of the flowing ability of the mixture.

[6] Specimens 2 by 2 by 1/8 inch in thickness.

[7] Forest Products Laboratory intermediate-capacity toughness machine; unnotched specimen, 3/8 inch wide by nominal 1/8 inch thickness by 3-1/2 inches long, tested over 2-1/2-inch span.

[8] Elongation immediately before fracture, measured over a 2-inch gage length.

[9] Pulp-property tests were not made on these modified pulps.

[10] Ground wood was prepared from white spruce.

[11] Cook 5083-N contained black gum in admixture with the sweet gum.

[12] Results of tests made at the Forest Products Laboratory.

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