Effect of Maleic Anhydride Treatment on Steam and Water Absorption of Wood Polymer Composites Prepared from Wheat Straw, Cane Bagasse, and Teak Wood Sawdust Using Novolac as Matrix

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ABSTRACT: Wheat straw, cane bagasse, and teak sawdust (agrowaste) were sieved up to a 425-μm mesh size and employed for sheet preparation with and without maleic anhydride (MA) treatment using Novolac resin in a 50 : 50 (w/w) ratio. The shore D hardness of MA treated and untreated wood polymer composites (WPCs) was measured. The MA treated WPCs showed 2–3 times more hardness than that of the untreated respective WPCs. Moisture absorption had a detrimental effect on the mechanical properties of the WPCs. MA treatment restricted swelling and water and steam absorption in the agrowaste. Teak sawdust showed the best results in all respects among the three WPCs. © 2000 John Wiley & Sons, Inc. J Appl Polym Sci 77: 2963–2967, 2000

Key words: maleic anhydride; wood polymer composite; Novolac resin

INTRODUCTION

Wood polymer composites (WPCs) have attracted research in plastics and wood technology. In some low grade wood species it has been reported that the mechanical properties of WPCs are better than the pure wood of corresponding species.[1] The capability of these materials as replacements for the consumption of wood up to a certain limit has enchanted the environmentalists as well.[2] The main obstacle that limits the applications of WPCs is the compatibility between plastics and natural agrowaste material.[3] There are different reasons for the incompatibility between plastics and fiber-based filler. Accordingly, various types of remedies have been suggested to overcome this problem.[4–8] EL-Barbary[9] suggested peroxide bleaching of rice straw and bagasse. Dong et al.[10] suggested a corona treatment to improve tensile properties. It is also reported[11,12] that alkali treatment improves mechanical properties. Water absorption affects the mechanical properties of WPCs.[13] Wood can be thermoplasticized for extrusion and molding purposes. Thermoplasticization may be achieved by esterification, etherification, and grafting reactions.[4] Esterification serves to increase the compatibility by replacing the –OH groups, which are prone to moisture absorption, in the cellulose.[14,15]

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EXPERIMENTAL

Wheat straw, cane bagasse, and sawdust were ground and sieved up to a mesh size of 425 μm. The weight ratio of the agrowaste to resin (50 : 50, w/w) was taken for the preparation of WPCs.

Novolac resin was prepared in the laboratory by reacting phenol with formaldehyde in a mole ratio of 1:0.83 in the presence of oxalic acid (1.5% phenol) as the catalyst; the resin was then ground to a fine powder. Selected agrowaste and Novolac resin (50 : 50 w/w) were separately mixed in a powder blender for about 10 min. The blended material was worked at 100°C for 5 min on a heated two-roll mill. The wood–polymer mix was then cooled and pulverized. Hexamethylene tetramine (12% resin) and calcium oxide (3% resin) were used as the curing agent and activator, respectively, and were then intimately mixed with the pulverized material.[16]

The pulverized material was molded to 2 mm thick sheets in a compression molding machine. The molding was carried out at 165 ± 5°C for 4 min employing pressure in the sequence of 4.8, 9.8, 14.7, and 19.6 MPa with a duration of 1 min each. The mold was then cooled under pressure by circulating cold water, and the molded sheet was ejected from the mold after releasing the pressure.

The agrowastes were esterified by using 2% maleic anhydride (MA) in xylene keeping the agrowaste at a solvent ratio of 1 : 20 (w/v). The soaking of MA was allowed for 18 h at 65°C. The treated material was filtered out and dried in an oven at 60°C till constant weight.

The hardness of untreated and MA treated WPCs was measured with a shore D hardness tester. The WPCs were allowed to swell for 2–30 h in water at ambient temperature and in steam (at 100°C) at atmospheric pressure.

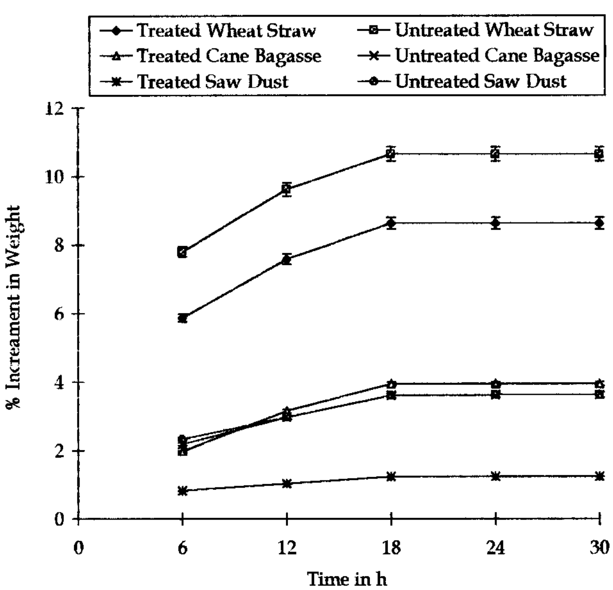

Figure 1 The water absorption in WPCs prepared from MA treated and untreated wheat straw, cane bagasse, and sawdust using Novolac as the matrix.

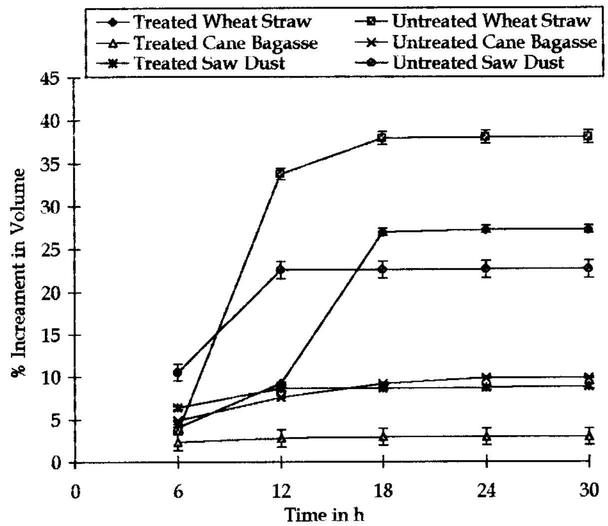

Figure 2 The swelling due to water absorption in WPCs prepared from MA treated and untreated wheat straw, cane bagasse, and sawdust using Novolac as the matrix.

RESULTS AND DISCUSSION

Water Absorption and Water Swelling of MA Treated and Untreated Wheat Straw, Cane Bagasse, and Sawdust Novolac (50:50) WPCs

The samples based on MA treated and untreated wheat straw, cane bagasse, and teak sawdust along with Novolac as a binding matrix were tested for water absorption for from 2 to 30 h. Figure 1 implies the trend in water absorption, while Figure 2 represents the percent water swelling. Teak sawdust MA treated and untreated samples show the least water absorption. The rate of absorption is linear up to 24 h in all three of the fillers individually containing WPCs. It gives a constant value after 26 h onward. The trend of water absorption is teak sawdust < cane bagasse < wheat straw in both the MA treated and untreated WPCs. The values obtained for water absorption in treated cane bagasse and untreated teak sawdust lies nearby. The rate of water absorption in untreated cane bagasse samples is higher compared to the treated cane bagasse samples. Although in the MA treated and untreated cane bagasse the amount of initial water absorption of untreated samples lies above that of

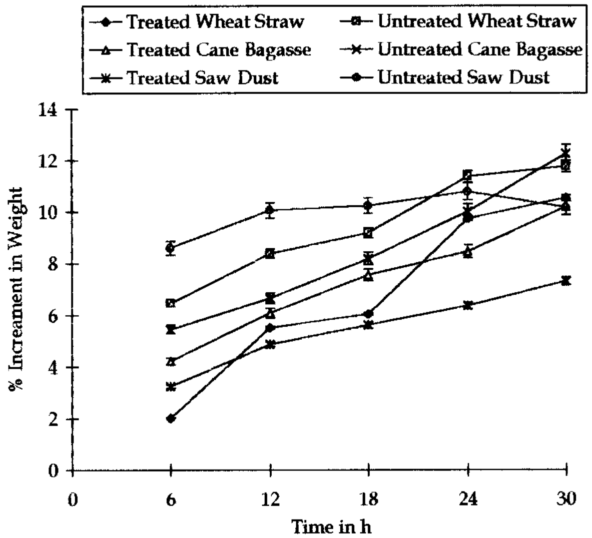

Figure 3 The steam absorption in WPCs prepared from MA treated and untreated wheat straw, cane bagasse, and sawdust using Novolac as the matrix.

treated samples up to 10 h, the rate of further water absorption in treated samples increases up to 30 h.

In contrast with the results of the percent water absorption, the percent water swelling in untreated wheat straw has the highest value and the treated cane bagasse has the lowest (Fig. 2). The percent water swelling of treated sawdust and untreated cane bagasse polymer composites lies nearer to each other. Untreated sawdust and treated wheat straw show a moderate percent water swelling at the end of 30 h.

Steam Absorption and Steam Swelling of MA Treated and Untreated Wheat Straw, Cane Bagasse, and Sawdust Novolac (50:50) WPCs

The results of the percent steam absorption and percent steam swelling are illustrated in Figures 3 and 4, respectively. Observe from the results that the absorption of steam increases up to 30 h in MA treated and untreated WPCs, but the rate of steam absorption in untreated WPCs is higher than the MA treated respective WPCs.

Swelling also increased with an increase in time up to 30 h in the MA treated and untreated WPCs. It was also observed that the percent swelling in MA treated WPCs was less than that in untreated WPCs. Like the results of the water swelling, the treated cane bagasse exhibited the least swelling among all three composites.

The shore D hardness was recorded for MA treated and untreated WPCs that were employed for water and steam absorption. The results in Table I show that the hardness decreases with an increase in time for water and steam absorption. The decrement in hardness with the increment in time for both MA treated and untreated WPCs occurred up to 30 h. The MA treated WPCs showed greater hardness than untreated WPCs.

DISCUSSION

The WPCs prepared from wheat straw, cane bagasse, and teak sawdust with Novolac showed a variation in absorption of water for 6–30 h. The maximum percent absorption of water in untreated WPCs was observed in wheat straw, while sawdust and cane bagasse showed more or less the same absorption of water. This may be due to the nearly same proportion of the chemical components present along with the cellulose.[17] The higher amount of water absorption might be due to the loose crisscrossed chemical structure of cellulose and lignin in the wheat straw. In the bagasse, and especially in the sawdust, the lignin contents are more crisscrossed with the cellulosic structure and hence the structure becomes compact, which results in less penetration of water. However, in both WPCs (sawdust and cane bag-

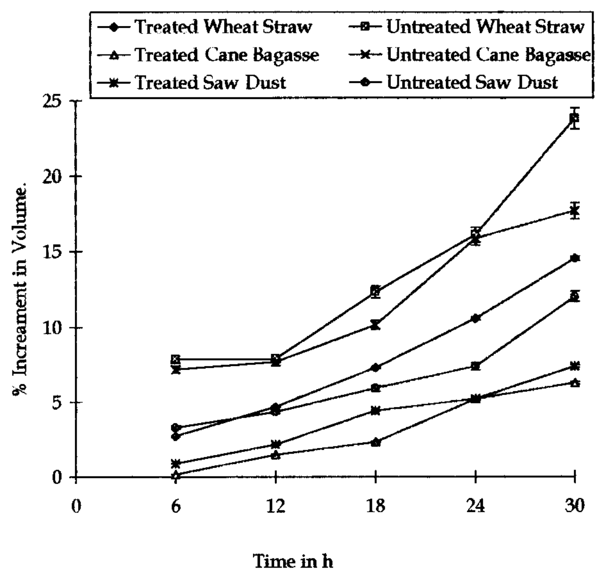

Figure 4 The swelling due to steam absorption in WPCs prepared from MA treated and untreated wheat straw, cane bagasse, and sawdust using Novolac as the matrix.

Table I Shore D Hardness Due to Water and Steam Absorption of WPCs Prepared from MA Treated and Untreated Wheat Straw, Cane Bagasse, and Teak Sawdust Using Novolac as Matrix

		Hardness after			Hardness after			Hardness after	
Time (h)	Sample	Water Absorption	Steam Absorption	Sample	Water Absorption	Steam Absorption	Sample	Water Absorption	Steam Absorption
00	TWS	90	90	TCB	92	87	TSD	94	94
	UTWS	84	78	UTCB	90	82	UTSD	90	86
06	TWS	90	88	TCB	91	85	TSD	93	92
	UTWS	83	75	UTCB	90	80	UTSD	91	84
12	TWS	86	87	TCB	90	84	TSD	92	91
	UTWS	80	75	UTCB	88	78	UTSD	88	82
18	TWS	83	85	TCB	89	84	TSD	91	90
	UTWS	78	74	UTCB	86	76	UTSD	87	81
24	TWS	83	84	TCB	89	78	TSD	90	87
	UTWS	76	73	UTCB	85	75	UTSD	87	79
30	TWS	83	82	TCB	89	76	TSD	90	85
	UTWS	76	65	UTCB	84	75	UTSD	86	79

TWS, treated wheat straw; UTWS, untreated wheat straw; TCB, treated cane bagasse; UTCB, untreated cane bagasse; TSD, treated sawdust; UTSD, untreated sawdust.

asse) the cellulosic structure is more compact as compared to wheat straw composites.

The percent increase in volume was observed less in bagasse WPCs and was maximum in wheat straw. The reason for the smaller increase in volume in bagasse is its spongy structure of pith that absorbs more water, but the volume is affected less. The hardness of wheat straw composite is also less than the bagasse and sawdust WPCs, which strengthens our results of water absorption.

The steam absorption is responsible for the higher penetration in the cell wall and insert inside of the intermolecular structure of the cellulosic part. Thus, the increment in the weight percentage is more with respect to water absorption. The volume percentage is also higher in steam treatment because the penetration of steam is responsible for breaking the hydrogen bonding, and thus more free volume becomes available. This results in an increase in swelling. The hardness is affected by the steam treatment as the free volume increases, thus decreasing the hardness.

The results of treated and untreated WPCs with respect to cellulosic material were compared. The increase in weight and volume, which was due to water and steam absorption, resulted in a decrease in the hardness and the hardness increased with the MA treatment. Through chemical reactions, an organic chemical can be added to the hydroxyl groups on wood cell walls with the help of a permanently bonded chemical.[18] Thus, MA treatment is responsible for reacting with free –OH groups of the cellulosic structure and with Novolac[15]; it behaves as a compatibilizer, increases mechanical properties, and decreases swelling behavior.

CONCLUSION

Because of its loosely arranged skeleton, wheat straw had the highest absorption of water swelling among the composites. The greater absorption of water in MA treated bagasse composites with respect to untreated fiber composites was due to the spongy nature of the pith of the bagasse, which can absorb more water, but because of the chemical crosslinking of MA it cannot swell. The compact nature of teak sawdust, by virtue of its highly crisscrossed lignin, showed maximum hardness among MA treated and untreated respective composites. The penetration of steam and water in the composites resulted in the decrease in hardness.

REFERENCES

1. Khan, M. A.; Idris Ali, K. M. D. J Appl Polym Sci 1992, 45, 167.

2. Yam, K. L.; Gogoi, B. K.; Lai, C. C.; Selke, S. E. Polym Eng Sci 1990, 30, 11.
3. Mukherjee, R. R. Textile Dig 1955, 16, 86.
4. Hon, D. N.-S.; Chao, W. Y. J Appl Polym Sci 1993, 50, 7.
5. Maldas, D.; Kokta, B. V. J Appl Polym Sci 1990, 41, 185.
6. Yap, M. G. S.; Que, Y. T.; Chia, L. H. L. J Appl Polym Sci 1991, 43, 1992.
7. Georgr, I.; Bhagwan, S. S.; Prabhakaran, N.; Thomas, S. J Appl Polym Sci 1995, 57, 843.
8. Dos, N. L.; Elawday, M. M.; Mansour, S. H. J Appl Polym Sci 1991, 42, 2589.
9. EL Barbary, E. H. J Sci Ind Res 1998, 57, 27.
10. Dong, S.; Sapieha, S.; Schreiber, H. P. Polym Eng Sci 1993, 33, 6.
11. Prasad, S. V.; Pavithran, C.; Rohatgi, P. K. J Mater Sci 1993, 18, 1443.
12. Nada, A.-A. M. A.; Fahmy, Y.; Abo-Yousef, H. E. J Sci Ind Res 1998, 57, 27.
13. Karmaker, A. C.; Hoffmann, A.; Hinrichsen, G. J Appl Polym Sci 1994, 54, 1803.
14. Mishra, S.; Naik, J. B. J Appl Polym Sci 1998, 68, 1417.
15. Mishra, S.; Naik, J. B. J Appl Polym Sci 1998, 68, 681.
16. Brydson, J. A. Plastics Materials, 5th ed.; Butterworths: London, 1989.
17. Luna, G. V.; Torres, C. A. GEPLACEA Bull 1985, 16.
18. Rowell, R. M.; Youngs, R. L. Research note FPL 0243; USDA Forest Service Forest Products Laboratory: Madison, WI, 1981.