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An enhanced model for prediction of young modulus of composite

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Abstract

This paper presents computer simulation model for prediction of young modulus for Wood Plastic Composite (WPC) properties. The effect on modulus of natural fibers which affect the strength and stiffness of the composites were studied. The results show that the percentage of void volume inside the fibers is reduced using the proposed model. The results are validated with the experimental data and it was shown that the results from simulations model are closed to the experimental result.

Keywords: Young's modulus; Wood Plastic Composites; Simulation model;

1. Introduction

Nowadays, computer simulation and modeling have becoming more popular to optimize the manufacturing conditions in chemical, automobile and aviation industry. Computer simulation offers an inexpensive means for analyzing the effects of various factors on the processing parameters and the final product. It also reduces the number of experiments including the need for expensive pilot plants. Recently, some of researchers are focusing on developing the mathematical model to predict the mechanical properties of wood composite. However, considerably less study has been done on simulation modeling in the field of Wood Plastic Composites(WPC). For better understanding of the fundamental aspects of WPC manufacturing process, there is a need for some computer simulation models.

The mechanical properties of fibre-filled composites are affected by a number of parameters such as fibre length, fibre orientation, fibre dispersion, fibre geometry as well as the degree of interfacial adhesion of fibre and matrix [1-5]. As the composite properties are dependent on the fibers Young's modulus, the effects on the fibre modulus has been investigated.

1.1. Background

Some related has been found in the field of composites. Monette.*et.al*.[6] suggested a computer model for all the theoretical understanding of the concept of the critical fibre length in composite. Similarly, Termonia [7] presented

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a computer model to study the effect of fibre characteristic on the mechanical properties of short fibre-reinforced composites. On the other hand, Shuming Suo [8] developed a computer simulation model for simulating structural particle board manufacturing process.

In [9], multi scales numerical analysis of non-isothermal polymeric flow of fibre suspensions by numerical simulation was proposed whereas Vaidyanathan [10] did the computer aided designing of the fiber reinforced polymer products to meet a set of target properties using two stage optimization problems. The design of a chemical storage tank was used as a case study. A procedure to obtain accurate solutions for heat conduction problems in composite media was presented in [11]. The governing partial differential equation is cast into an integral form by the application of the boundary integral theory. In addition, Melnik [12] proposed computationally efficient algorithms for modeling and degradation as well as spiking phenomena in polymeric materials. Similarly, a flexible approach to modeling and simulation of polymeric composite materials processing using object oriented technique was presented in [13].

2. Prediction Model

Most of the previous mechanical models have considered the wood fibers equivalent to the synthetic fiber having the uniform modulus of elasticity. However, wood fiber being a natural product shows a significant difference in the composition and the strength. It was observed that the models predict better results for the composites using synthetic fibers like carbon fibers, fibre glass etc. The predictions made for the strength of wood plastic composites were found to be very hypothetical and have significant difference with the experimental results. According to these models, Young’s modulus can be predicted using the following equations.

Parallel model or Rule of Mixtures (ROM):

$$E_c = E_0(1-V_f) + E_f V_f \quad (1)$$

Series Model or Inverse Rule of Mixtures (IROM):

$$E_c = \frac{E_0 E_f}{V_f E_0 + (1-V_f)E_f} \quad (2)$$

where, E_0, E_f and E_c is the modulus of elasticity of the pure polymer, fiber and composite respectively, and V_f is the volume fraction of the fiber.

2.1. Proposed Model

None of above models consider the effect of changes in fibers young’s modulus while fabrication. The modulus of the fibre dependent on the moisture content of the fibers, as well as the relationship between the moisture content of wood and its mechanical properties below the fiber saturation point (FSP) which is determined as follows [14]:

$$E_{MC} = E_{12}\left(\frac{E_{12}}{E_G}\right)^{\left(\frac{12-MC}{MT-12}\right)}. \quad (3)$$

where E_{MC}, E_{12} and E_G are the modulus of wood at the moisture content (MC) of interest, at 12% moisture content and at the green condition respectively. The density of the fibers also depends on the moisture content of the wood. If the specific gravity of green wood (G_B) is known, then the density of wood at particular moisture content can be calculated as follows [14].

$$\rho_{MC}(kg/m^3) = 1000\left(\frac{G_B}{1-0.265\left(\frac{30-MC}{30}\right)G_B}\right)\left(1+\frac{MC}{100}\right). \quad (4)$$

Fig. 1 illustrates the processes involve in the simulation model. At the beginning of the program, all variables are declared and the modified value of Young's modulus was calculated. The iterative loop was developed to calculate the values of modulus from different models at different percentage of the fibre volume. The simulation values were validated with the experimental results. The algorithm was developed to fit different kinds of wood plastic.

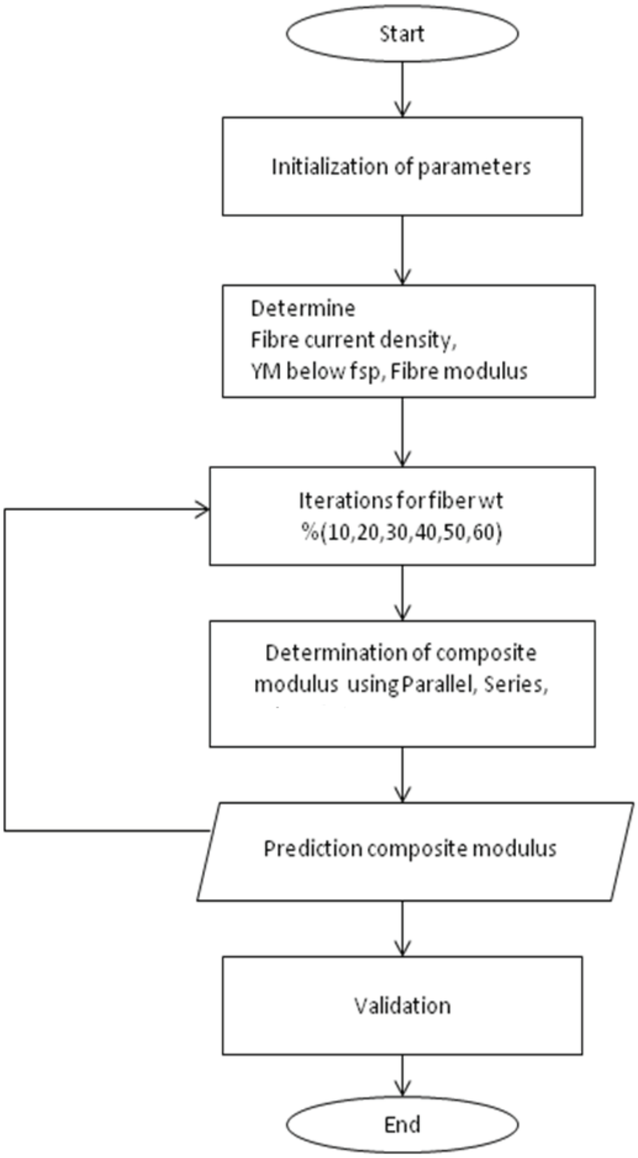

Fig. 1: Flow chart of the methodology

3. Results and Discussion

In the first phase, the simulation models were run without modification and the results from simulation model are presented in the Table 1. It was observed that the Parallel model predicts the highest value of the young's modulus ranging from 3652 MPa to 17239 MPa, whereas Series model predict the lowest values ranging from 1506 MPa to 2772 MPa. Fig. 2 shows the simulation results, which is quite low in comparison to the experimental results.

Table 1: Prediction of Young's Modulus through different models.

Vf (%)	7.36	15.17	23.46	32.29	41.7	51.76
Experimental	1630	2300	3400	3980	5010	5800
Series	1506	1637.5	1804.9	2025.4	2328.5	2772
Parallel	3652	6042	8578.8	11281	14160	17239

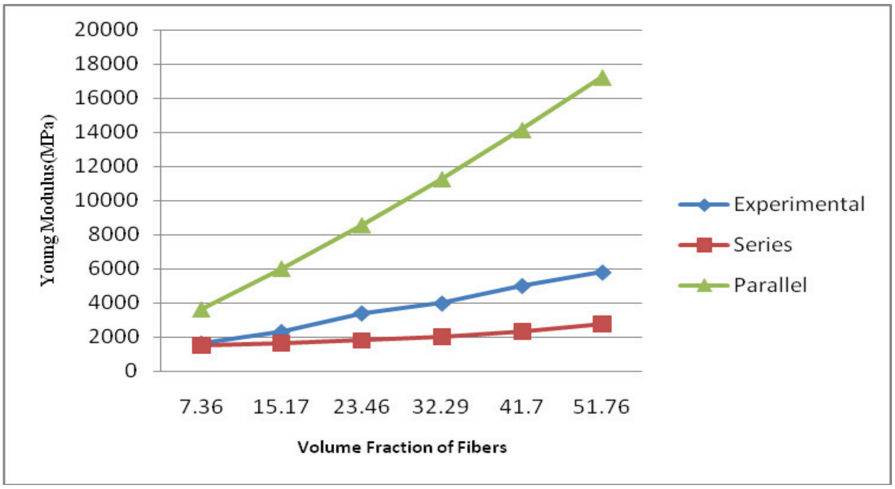

Fig. 2: Prediction of Young's Modulus with different models.

In the second phase, the simulation was done based on the modified parameters and the results are as shown in Table 2. It was observed that the predicted value for fibre modulus is 17253 MPa. It is found that the values of composite Young's modulus have dropped in most of the cases. Fig. 3 shows the simulation results, which is comparatively much lower and closer to the experimental values.

Table 2: Prediction of Young's modulus through different models in phase I.

Vf(%)	7.36	15.17	23.46	32.29	41.7	51.76
Experimental	1630	2300	3400	3980	5010	5800
Series	1501.5	1626.8	1784.7	1990.6	2269.6	2669.7
Parallel	2566.8	3804.9	5119.2	6519	8010.8	9605.6

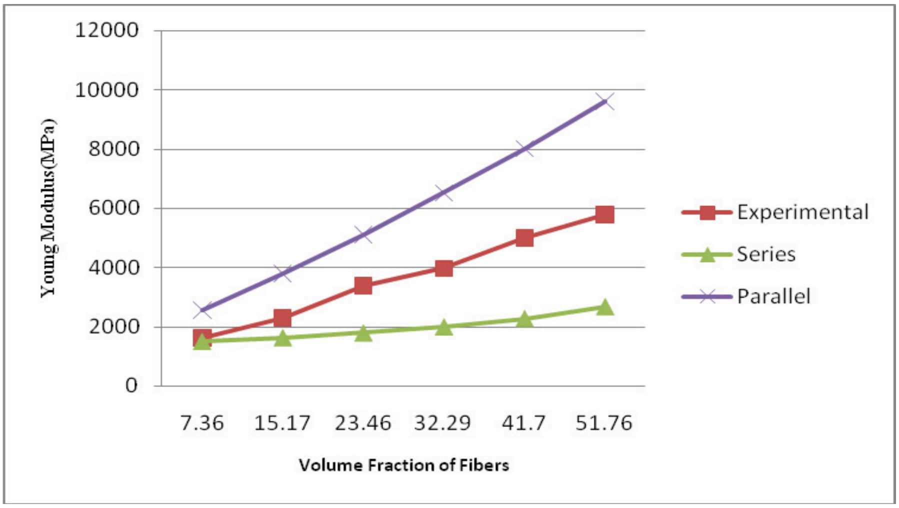

Fig.3: Prediction of Young's Modulus with modulus correction factor.

4. Conclusion

The simulations were run for all models. The values predicted by simulations were quite high when compared to the experimental results. However, after applying changes in fibre modulus, due to various stages of fabrication of the final composite, the simulation results were much improved and more close to experimental results

References

1. Liua, H., Yaoa, F, Xua, Y and Wu, Q. (2010), A novel wood flour (WF)-filled composite based on the microfibrillar high-density polyethylene (HDPE) and Nylon-6 co-blend. Bioresource Technology, Volume 101, Issue 9, May 2010, p. 3295-3297
2. Islam, M.S., Hamdan,S., Rahman, M.R Jusoh, I., Ahmen,A.S and Idrus,M., "Dynamis Young's Modulus, Morphological and Thermal Stability of 5 Tropical Light Hardwoods Modified by Benzene Diazonium Salt Treatment, BioResources,, Vol 6, No 1 (2011).
3. Jördensa, S. Wietzkea, M. Schellera and M. Kocha, "Investigation of the water absorption in polyamide and wood plastic composite by terahertz time-domain spectroscopy", Polymer Testing, Volume 29, Issue 2, (2010), p. 209-215.
4. Shimizu, H., Tsue, F., Chen, Z.-X. and Takahashi, Y. (2009), Effect of Surface Preparation on the Failure Load of a Highly Filled Composite Bonded to the Polymer-Monomer Matrix of a Fiber-Reinforced Composite. Journal of Prosthodontics, 18, p. 255–258.
5. Kim, J.K and Pal, K., "Wood Plastic Composite Foam Applications", Engineering Materials(2011) Volume 32, p. 165-172.
6. Monette L., Anderson M.P. and Grest G.S.: Polymer Composite. 14 (1993) 101.
7. Termonia Y.: J Polym. Sci. Polym. Phys. 32 (1994) 969.
8. Shuming S. .:Computer Simulation modeling of structural particle board.PhD Thesis ,University of Minnesota,(1991).
9. Zhang H. .:Computers and Chemical Engineering 32 (2008) 1523–1532 ,Elsevier
10. Vaidyanathan R. .: Computers chem. Engng Vol. 22, No. 6, pp. 801408, 1998 Elsevier Science
11. Onyejekwe O. O. .: Computers and Chemical Engineering 26 (2002) 1621_/1632 .Elsevier.
12. Melnik R.V.N. .: Computers and Chemical Engineering 27 (2003) 1473_/1484 Elsevier.
13. Potaraju S. .: Computers and Chemical Engineering 24 (2000) 1961–1980 Elsevier.
14. Forest Products Laboratory. Wood handbook—Wood as an engineering material. Gen. Tech. Rep. FPL-GTR-113. Madison, WI: US Department of Agriculture, Forest Service, Forest Products Laboratory 1999.