WATER ABSORPTION AND DIFFUSION PROPERTIES OF ARECA FIBER REINFORCED EPOXY AND VINYL ESTER COMPOSITES

Sunil Kumar M[1], S.G. Gopalakrishna[2]
Sujay M[3], Shiva Kumar H.R[4]

[1]*Department of Mechanical Engineering, KVG College of Engineering Sullia, D.K. Karnataka-(India)*
[2]*Department of Mechanical Engineering, Nagarjuna College of Engineering and Technology, Devanahalli, Bangalore, Karnataka- (India)*
[3,4] *Department of Chemistry and Centre for Multidisciplinary Research in Advanced Materials and Technology, KVG College of Engineering Sullia, D.K. Karnataka- (India)*

ABSTRACT

In this study, the areca bast fiber reinforced epoxy and vinyl ester composites were subjected to water immersion test in order to study the water absorption and diffusion properties under the room temperature. Areca fiber epoxy/vinyl ester composites containing 6, 8, 10, 12 and 14 weight percentage of fiber were prepared. The water absorption and diffusion properties of these composites sample were determined using standard weight gain method by immersing the sample in saline water at room temperature. It shows that moisture uptake increases with increase in fiber weight percentage due to increased voids and cellulose content. The diffusion rate also increased with increase of the fiber loading. All specimens showed a high rate of swelling at the beginning of the wetting test, but rate of swelling decreased asymptotically with time. The epoxy matrix shows moisture sensitivity due to interactions between some polar groups of the macromolecules and water molecules. This sensitivity increases with increasing degree of cross linking and also with polarity concentration of the molecular groups. All specimens of vinyl ester composites showed a high rate of water absorption and diffusion compared to specimens of epoxy composites due to their hydrophilicity.

Key Words: Areca Fiber, Diffusion Coefficient, Epoxy, Vinyl Ester, Water Absorption.

I. INTRODUCTION

During recent years, interest in using eco-friendly materials in engineering has been increased due to growing environmental awareness. As a result researchers are leading for renewable recyclable, sustainable, green, decomposable or biodegradable materials to replace some of the traditional engineering that are not environmental friendly [1]. The use of natural fibers as reinforcement in polymer composites for making low cost engineering materials has guaranteed recent years. It can be substituted for conventional non renewable reinforcing materials such as glass fibers [2]. The use of natural fibers and polyester matrix is highly beneficial because strength and toughness of the resulting composites are greater than those of unreinforced plastics [3].

The bio-fiber world is full of examples where cells or group of cells are designed for strength and stiffness. Cellulose is a natural polymer with high strength and stiffness per unit weight and it is the building materials for long fibrous cells. These cells can be found in the stems, leaves and seeds of plants [4].

Although several natural fibers has been used in composites for many years. Areca fiber is one of the rare materials used for making of composites. In this work areca bast is used for composites. In fact it is cellulose fiber possess several potential advantages such as, 1) their low density which makes it possible to obtain lighter composites 2) their good mechanical properties, 3) their bio-renewable character, 4) their ubiquitous availability at low cost and their modest abrasive character which ensures a greater longevity of a processing tools [4].

Epoxy and vinyl ester are considered as the best polymeric materials for many applications and widely used in industry as matrix materials of fiber reinforced composites due to their superior characteristics such as good mechanical properties and good resistance to chemicals [5]. Epoxy and vinyl ester composites have many advantages such as lower cost, lighter in weight and better performances over hermetic packages [6].

In this work, the water absorption and diffusion coefficients of areca fiber reinforced epoxy and vinyl ester composites have been studied.

The water absorption is caused due to the hydrophilic nature of fiber due to its polarity owing to the free hydroxyl groups of cellulose and lignin. These hydroxyl groups can hold the water molecules by hydrogen bonding. Water absorption into composite materials is addressed by three different mechanisms. The main process consists of diffusion of water molecule inside the micro holes between polymer chains. This involves direct diffusion of water into matrix and to a much lesser extent into fibers. In addition moisture penetration can also occur through the fiber ends, which serves as conduits for water transport. Another mechanism is capillary transport to the gaps and flows at the interfaces between fibers and polymers due to the incomplete wet ability and impregnation and also transport through micro cracks in the matrix formed during the compounding process [7,8].

II. EXPERIMENTAL

2.1 Materials

Raw materials used in experimental work were,

1) Natural fiber (areca bast)
2) Resins (epoxy and vinyl ester)
3) Boron fluoride (promoter)
4) Methyl ethyl ketone peroxide (catalyst)
5) Cobalt Napthanate (accelerator)
6) Aradur HY95 1(hardener)

2.2 Methods

The samples were prepared with 6%, 8%, 10%, 12%, 14% weight mass fractions of fibers. For different mass fraction of fibers a calculated amount of epoxy resin and hardener (10:1) by weight thoroughly mixed and gently stirred. The load was put on cavity. The whole is left for 24 hours and then removed for curing in the oven. Then composites cut for water absorption testing. Same procedure is taken for vinyl ester matrix based composite in which additional accelerator, catalyst and promoter were mixed and the same procedure was continued as done for epoxy composites [10].

Water absorption testing of composites has been carried out by taking rectangular bars (approximately 3.2 mm thick, 75 mm long and 25 mm width) from composite sheet as per ASTMD570. The samples were dried in oven at 50^0C for 24 hours, and removed, cooled and weighed. Then samples were immersed in sea water at the room temperature. For every 24 hours samples were removed and wiped using cotton and weighed until samples attain saturation [11, 12, 13].

The change in mass of the sample in terms of percentage is calculated by the expression,

M= (Ms-Mi)/Mi×100

Where, **Ms**is the mass of the sample after immersion

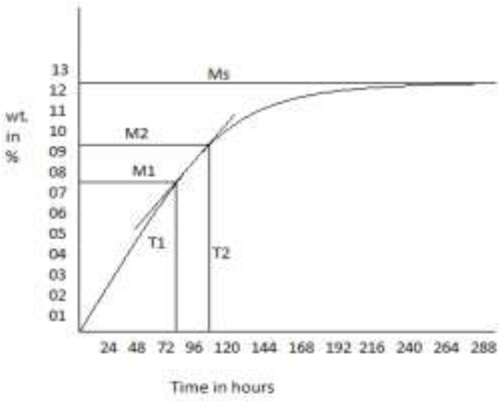
Mi is the initial mass of the sample [14, 15].

The diffusion coefficient (D) was calculated by the formula,

$$D = 3.142\left(\frac{t}{4Ms}\right)^2 \times \left(\frac{M2-M1}{\sqrt{T2}-\sqrt{T1}}\right)^2$$

$\left(\frac{M2-M1}{\sqrt{T2}-\sqrt{T1}}\right)^2$is the slope.

Where M_2 and $M_1$are the moisture content at time t_2 and t_1 respectively, **h** is the thickness of the specimen in mm and **Ms** is the maximum moisture uptake. It is graphically represented below in figure, [12,16]



III. RESULT

Generally water absorption in polymer composites is an activated absorption-diffusion process. The water molecule first enters into surface of matrix and then diffuses through the bulk of the polymer composites. It also enters through nanopores of the composites. The amount of water absorption depends on time, temperature, equilibrium moisture content. When the time increases the proportion of the water absorption decreases [17].

In the figure (1) and (2) water content of composite increased with time and later became saturation. Water is predominantly absorbed at fiber interface and matrix. All specimens showed high rate of absorption and decreases asymptotically with time. Water absorption increases with increase in fiber loading, because asearlier said in the introductory part, fibers containing cellulose which having polar groups are attracted towards water molecules.

Comparisons of epoxy and vinyl ester composite materials are quite interesting. It was observed that water absorption in vinyl ester is more when compared to epoxy composite materials. It is because of ester group present on vinyl ester which is attracted towards water molecules. And graphical representation shows epoxy has resistance power towards water molecules.

Here,

A, F= 6% fiber

B, G= 8 % fiber

C, H= 10 % fiber

D, I= 12 % fiber

E, J= 14 % fiber

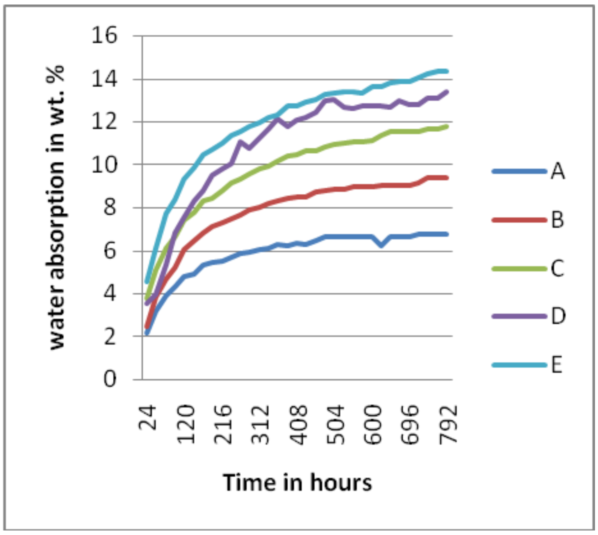


Fig. 1: Water absorption test for epoxy-areca bast composite materials

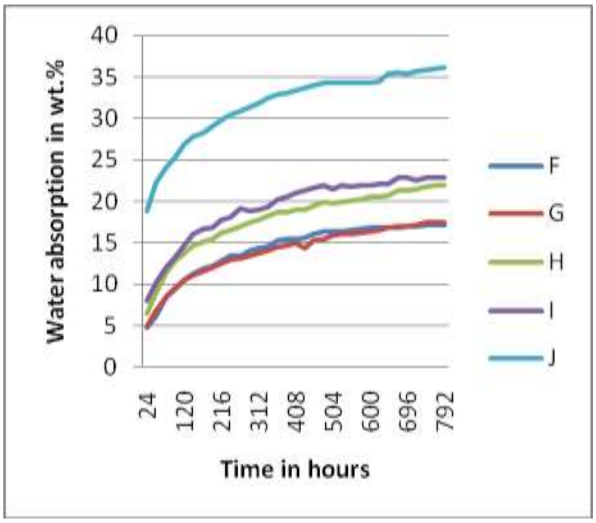


Fig. 2: Water absorption test for vinyl ester-areca bast composite materials

Wt. of fibre in %	D.C of Epoxy CM in m^2/s	D.C of Vinyl Ester CM in m^2/s
6	0.171×10^{-14}	1.062×10^{-14}
8	0.289×10^{-14}	1.120×10^{-14}
10	0.469×10^{-14}	1.142×10^{-14}
12	0.673×10^{-14}	2.570×10^{-14}
14	0.504×10^{-14}	0.147×10^{-14}

3.1 Diffusion coefficients of epoxy and vinyl ester composites

By analyzing above data's, it shows that diffusion coefficient increases with increase in fiber content up to 12% of fiber and at 14%, it suddenly decreases in both epoxy and vinyl ester composite material. It is because of increase in clouding of fiber load which will resist to water molecules to diffuse through the nano-pores. When epoxy and vinyl ester composite materials are compared, it shows that vinyl ester composites having more diffusion rate compared to epoxy composites. More over mechanism of water absorption and diffusion coefficients are similar and they are directly proportional. This context can be observed by the obtained results that, water absorption and diffusion property is more in vinyl ester-areca bast composites compared to epoxy-areca bast composites.

IV. CONCLUSION

The absorption behavior and diffusion coefficient of epoxy and vinyl ester composite materials in sea water at room temperature and comparison of epoxy and vinyl estercomposites materials has been studied. Ultimate result shows that water absorption and diffusion coefficient increases with fiber loading. Water absorption is mainly because of areca fiber. If cellulose composition is more the more water is absorbed. Also these two properties are more in vinyl estercomposite materials compared to epoxy composite material. So it can be concluded that epoxy based composite material is more favorable against water absorption when compared to vinyl ester composite material. In this regard, the study may give platform for the further modifications for the marine applications as well as the materials used in moisture conditions.

Acknowledgment: The authors gratefully acknowledge to VGST-Govt. of Karnataka for financial support.

REFERENCE

[1] Reza Masoodi and Krishna M. Pillai, A study on moisture absorption and swelling in bio-based jute-epoxy composites, *Journal of Reinforced Plastics and Composites, 31(5)*,2012, 285-294.

[2] H.N. Dhakal, Z.Y. Zhang, M.O.W. Richardson, Effect of water absorption on the mechanical properties of hemp fiber reinforced unsaturated polyester composites, *Composites Science and Technology*, 2006.

[3] Y. Seki, K. Sever, M. Sankanat, I. Sen, A.Aral, Jute/ Polyester composites: The effect of water aging on the interlaminar shear strength(ILSS), 2011.

[4] Sabu Thomas, Laly A. Pothan, Natural Fiber Reinforced Polymer Composites editions des archives contemporaines,NewYork.

[5] Dinh Van Chau, A study on water absorption and its effects on strength of nano-organoclay-epoxy composites, *Journal of AppliedSciences,12(18)*,2012,1939-1945

[6] Sabu Thomas, Kuruvilla Joseph, Sant Kumar Malhotra, Koichi Goda, and Meyyarappallil, Sadasivan Sreekala, *Polymer composites* Volume-1,Wiley-VCH

[7] Shirangi M.H., Fan X.J., Michel B. Mechanism of moisture diffusion, hygroscopic swelling and adhesion degradation in epoxy molding compounds,2008

[8] Chi-hung Shen and George S. Springer, Moisture absorption and desorption of composite materials, *Journal of Composite Materials, vol. 10*, 1976.

[9] Girisha.C, Sanjeevamurthy, Gunti Ranga Srinivas, Sisal/Coconut Coir Natural Fibers – Epoxy Composites: Water Absorption and Mechanical Properties, *International Journal of Engineering and Innovative Technology (IJEIT) Volume 2, Issue 3*,2012.

[10] Sridhar Sathyanarayanan1, Investigation Of Moisture Diffusion Process In Fibre Reinforced Composites By Computing Diffusivity Factors Along 3-Perpendicular Directional Axes Of Hot Wet Temperature Resin Matrix, SSRG *International Journal of Mechanical Engineering (SSRG-IJME)–volume2*,2014.

[11] L. Kumosa, B. Benedikt, D. Armentrout and M. Kumosa, Moisture Absorption Properties of Unidirectional Glass/Polymer Composites Used in Composite (Non-Ceramic) Insulators, Composites-Part A, 2004.

[12] Sreejith Muthirakkal, H N R Narasimha Murthy, Munishamaiah Krishna, Kudamara S Rai and Jeena S Karippal, Hygrothermic behavior of Carbon/Vinyl ester, Glass/ Vinyl ester, Carbon/ Epoxy and Glass/ Epoxy composites, *Iranian Polymer Journal, 19(2)*, 89-103, 2010.

[13] Srinivasa C.V., Bharath K.N.,Water absorption behavior of areca fiber reinforced polymer composites, *International Journal of Materials and Biomaterials Applications 2(2)*,12-14, 2012.

[14] Sheelan R. Areef, The study of solution absorption and diffusion coefficient in epoxy composite reinforced with glass fibers, *Engineering and Technology, vol. 26*, 2008

[15] Younus Khalaf Jabber, Study the Effect of Absorption Solution for Same Composite Polymeric Material, *International Journal of Science and Technology, Volume* , 2013

[16] A. Naceri, Moisture diffusion properties of fabric composite (glass fiber/epoxy resin), *vol. 2,* No. 2, 205-210,2009.

[17] Joannie W. Chin, Tinh Nguyen, KhaledAouadi, Sorption and diffusion of water, salt water, and concrete pore solution in composite materials, *Journal of Applied Polymer Science, vol. 71*, 483-492,1998.