Theoretical Modeling for Calculation Mechanical Properties of Biopolymer-Plant Fiber Composite

Ali I. Al-Mosawi[1]*, *Shaymaa Abbas Abdulsada*[2], *Muslim M. Ali*[3]
[1]Free Consultation, Babylon, Iraq
[2]College of Engineering, Materials Department, University of Kufa, Kufa, Iraq
[3]University of Missouri, Columbia, MO, USA

Abstract

Tensile and flexural strength of biopolymer polyhydroxyalkanoate reinforced with (20, 40, and 60) wt. % flax fibers were estimated theoretically by using ANSYS program version (11) under variation loading. ISO-R-527 and ASTM D790standards were used to modeling the tensile and flexural test samples respectively by ANSYS program. The theoretical data shows that high tensile and flexural strength value for polyhydroxyalkanoate after reinforcing with flax fibers and this strength will increase with increasing weight fracture of fibers. The theoretical results shows that high tensile strength value for polyhydroxyalkanoate after reinforcing with flax fibers due to high elastic modulus for these fibers and this strength will increase with increasing percentage of fibers and this agree with the experimental results obtained from tensile test.

Keywords: ANSYS program, biopolymer, mechanical properties, Plant fibers

****Corresponding Author***
E-mail: alialmosawi76@gmail.com

INTRODUCTION

Manufacturing technology of composite materials known as one of the simplest processes since centuries ago was used by Babylonians in the construction of their homes by mixing sawdust with clay to strengthen the material. [1] Composite material made from the integration of two materials or more and include blends and plastic which various in mechanical and physical properties. [2] The merge process lead to get new material with geometric and physical properties different from the properties of materials used in the composition. [3] General use of composites highly depends on mechanical and physical properties of these materials, so the study of these properties under the influence of forces and loads in different conditions is of great importance to determine the suitability of these properties to work place of these materials.[4] In nature there are many examples of composite materials such as cellulose fibers material with wood, while in the industry, reinforced by synthesis fibers are the most prevalent.[5] For the manufacture of composites must provide two materials:

(1) Matrix materials: either be (i) metallic materials composed of metals and their alloys is characterized by heavily weight and high durability; or may be (ii) ceramic materials and characterized by lightweight and high resistance to high temperatures but with a weak resistance to the impact forces;[6] or (iii) polymeric materials which are the most commonly used and widespread due to its good mechanical properties and thermal, and examples of polymeric materials

epoxy, phenol, polyester and natural resins. [7]

(2) Reinforcing material: Must be availability two features in these materials, a high resistance and low ductility so that it can reinforced matrix material.

There are several ways to reinforcement including: by reinforcement particulate (larger than the (1 μm) diameter) in different forms, as well as reinforcement by dispersion(less than a (0.1μm) diameter), but the most common methods of reinforcement is reinforcement by fibers due to its great strength compared to the resin material, and these fiber can be continuously, chopped or as woven roving. [8]

The aim of fibers reinforcement is to improve the properties of resins such as compression strength, tensile strength, impact strength, hardness, pressure quality, et al., which will give these materials for use in heavy industrial applications. [9] These materials are called advanced composites so as to be differentiated from filled polymeric materials. [10,11] The fibers in this type of composites is the main responsible for carrying external loads, and more common types are glass fibers, carbon fibers, Kevlar fibers and plant fibers. [12]

Flax crop is considered one of the oldest fibers crops that used by human in his clothes industry. Flax is a strong plant fiber with an increase of strength of 20% in wet conditions and it can absorb 20% moist without wet. [13] Properties of flax fibers were shown in Table 1.

Table 1. *Properties of Flax Fibers.* [13]

Tensile strength (MPa)	Stiffness (KN/mm^2)	Elongation at break (%)	Density (g/cm^3)	Moist absorption (%)
800–1500	60–80	1.2–1.6	1.4	7

MECHANICAL PROPERTIES

Tensile Strength

Tensile strength is a measure of the material ability to resist static force that is trying to pull the material and broken. Fibrous composites consist of a strong brittle fiber immersed in the resinous matrix.

Initially, the composite material will be started in elongated in a linear mode as a response to subject stress and with continued loading gets deviation as a result of the arrival of material to yield point, while the fibers will continue to elongate and resistance until the collapse resistance.

When crushed matrix composite materials fail entirely. [1]

Tensile strength can be obtained from the following formula:

$$\sigma = P/A \qquad \text{Eq. (2)}$$

where σ is the tensile strength (N/m^2), P the test load (N), and A is the cross-section area of sample (m^2).

Flexural Strength

The test beam is under compressive stress at the concave surface and tensile stress at the convex surface. [14] Flexural strength can be obtained from the following formula:

$$\sigma = F \times S = \frac{3PS}{2bt^2} \qquad \text{Eq. (1)}$$

where F is the maximum load (N), S the distance between loading points (mm), b the sample width (mm), and t is the sample thickness (mm).

WORK PROCEDURE

(1) Work materials: polyhydroxyalkanoate and flax fibers.

(2) Standard samples: ISO tensile standard (ISO-R-527) and ASTM flexural standard (ASTM-D790) have been was used in this work.
(3) Software: ANSYS program version (11) was used to estimated tensile and flexural strength for biopolymer polyhydroxyalkanoate before and after reinforced with different weight fracture flax fibers (20, 40, and 60%). Specific properties for both resin and fibers was input in database of ANSYS program, as well as standard shape of samples, and applied different amount of loads to make a theoretical emulation to experimental tensile and flexural test, and then map out the acquired data after applying the loads. Table 2 shows the specifications used to draw test samples.

Table 2. *Specifications Used to Draw Test Samples.*

Sample	Model	Type of element	Element no.	Nodes no.
Tensile	Linear	Solid 185 Geometry 8 Nods 3-D Modeling	3922	10961
Flexural	Linear	Solid 185 Geometry 8 Nods 3-D Modeling	5145	10290

RESULTS AND DISCUSSION

Tensile strength of biopolymer polyhydroxyalkanoate resin before reinforcement was shown in Figure 1, where we observed low tensile strength of this resin, when exposed to the loads. This is in general, because of considering resins as a brittle material when examined though the obtained experimental results.

After reinforcing by fibers this property will be improved greatly as shown in Figure 2 which represent the tensile strength to polyhydroxyalkanoate after reinforcing with (20%) flax fibers, where the strength of resin will increase due to the fibers will withstand the maximum part of loads.

The tensile strength will be increased as the fibers percentage addition increased as illustrated in Figures 3 and 4 which represent tensile strength to polyhydroxyalkanoate after reinforcing with (40%) and (60%) from flax fibers, respectively.

These fibers will be distributed on large area in the resin which will be improved tensile strength greatly. Flexural strength as mentioned above, the biopolymer is brittle; therefore, its flexural strength is low before reinforcement as shown in Figure 5.

In the same behavior, flexural strength will also increase and the reason for this is that fibers will bear most of load. This situation increases with increase in the proportion of fibers added as in Figures 6–8.

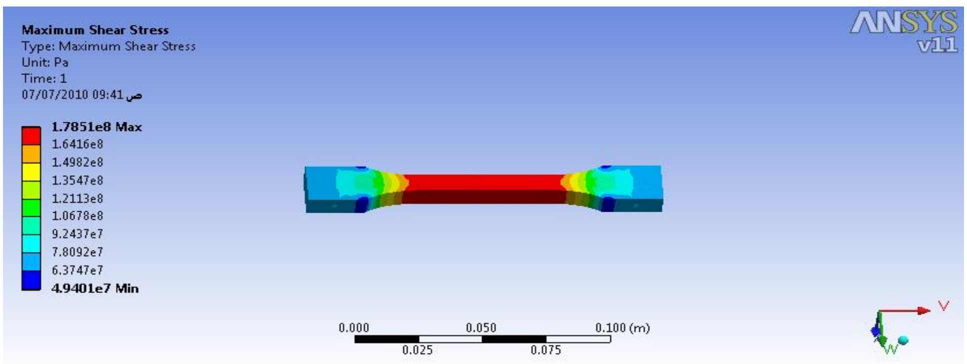

Fig. 1. *Tensile Strength to Polyhydroxyalkanoate before Reinforcement.*

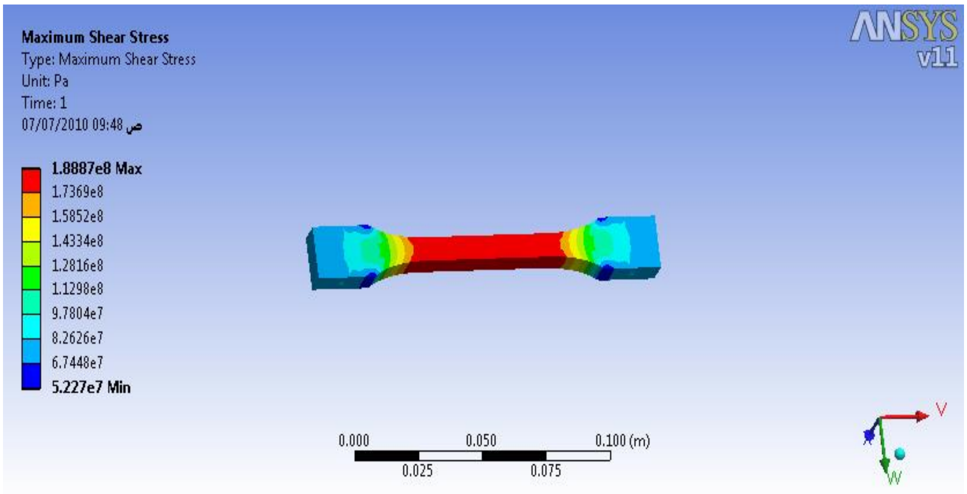

Fig. 2. *Tensile Strength to Polyhydroxyalkanoate After Reinforcing With 20 wt. % Flax Fibers.*

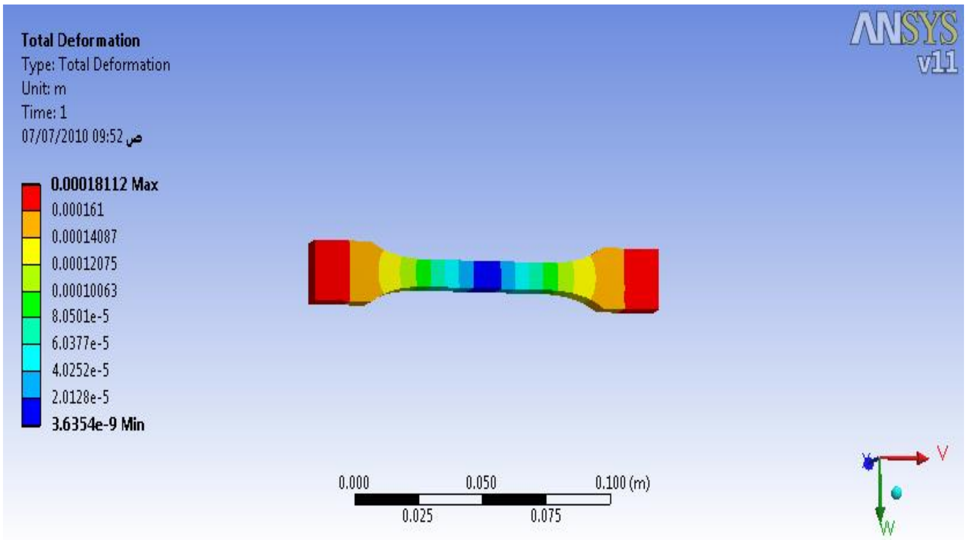

Fig. 3. *Tensile Strength to Polyhydroxyalkanoate After Reinforcing With 40 wt. % Flax Fibers.*

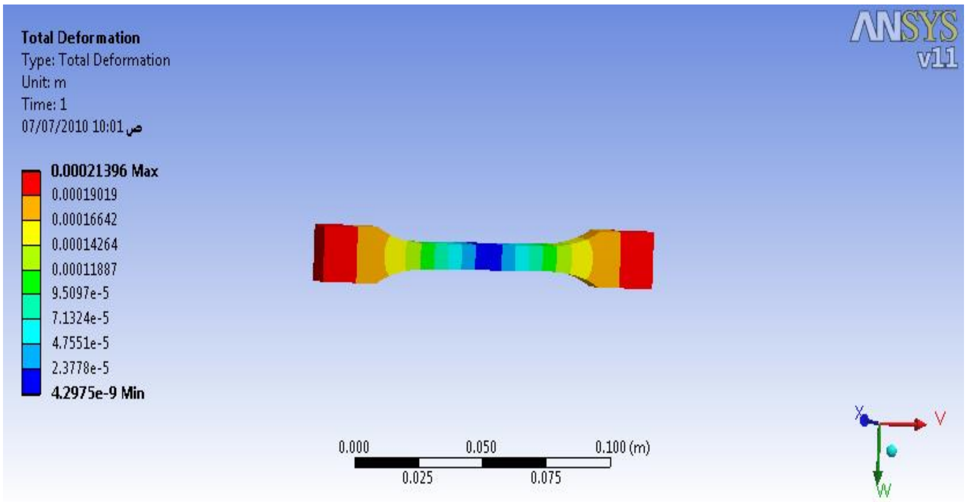

Fig. 4. *Tensile Strength to Polyhydroxyalkanoate after Reinforcing with 60 wt. % Flax Fibers.*

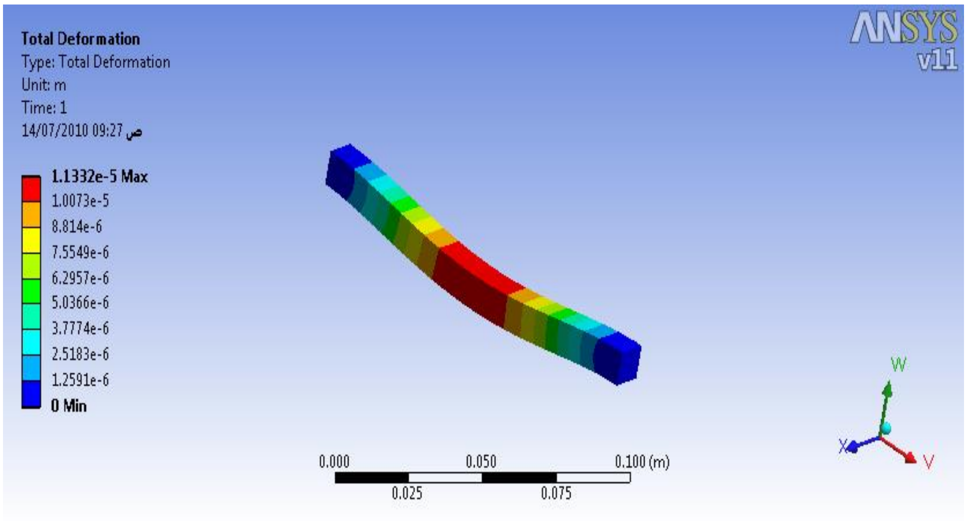

Fig. 5. *Flexural Strength to Polyhydroxyalkanoate before Reinforcement.*

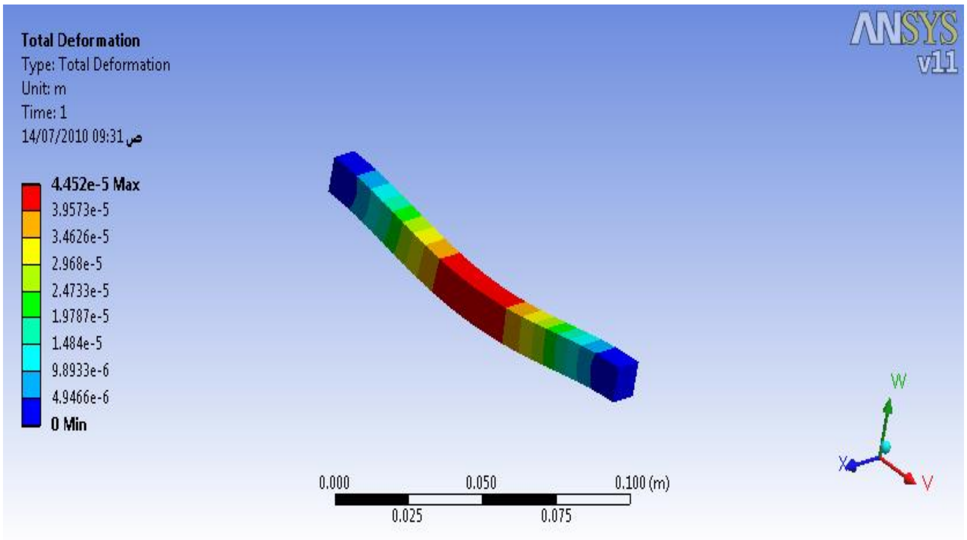

Fig. 6. *Flexural Strength to Polyhydroxyalkanoate After Reinforcing With 20 wt. % Flax Fibers.*

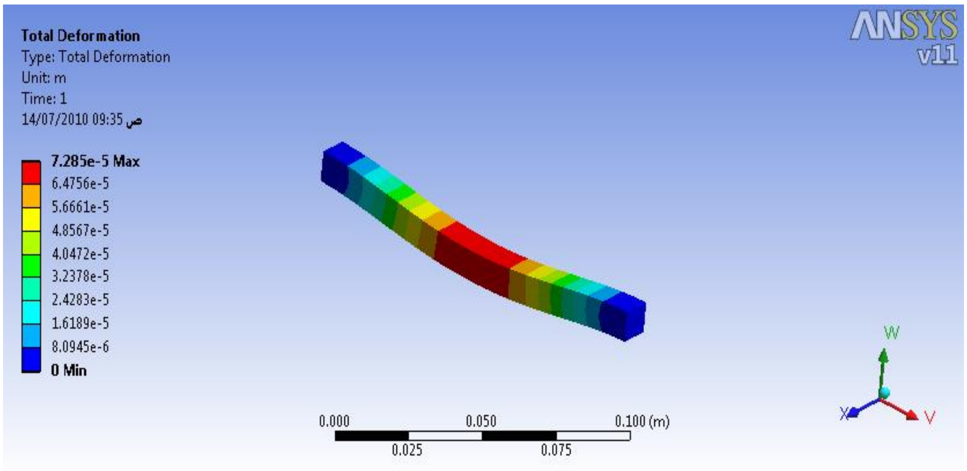

Fig. 7. *Flexural Strength to Polyhydroxyalkanoate after Reinforcing With 40 wt. % Flax Fibers.*

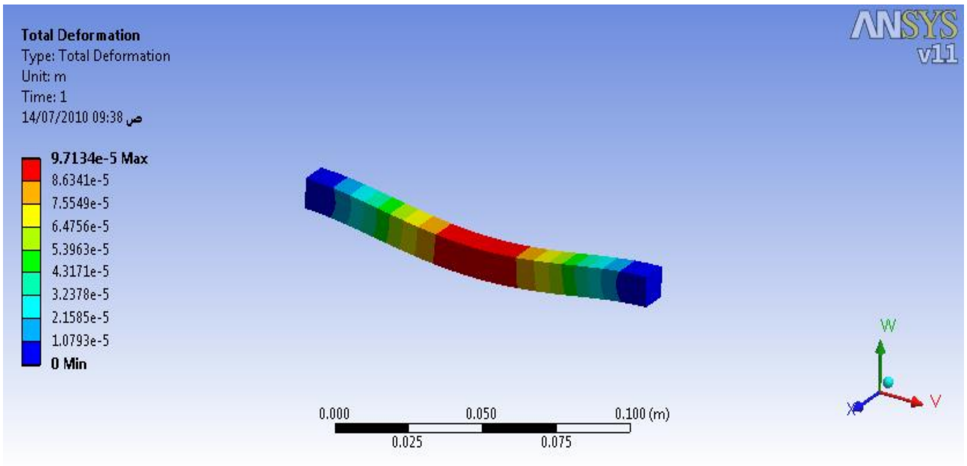

Fig. 8. *Flexural Strength to Polyhydroxyalkanoate after Reinforcing With 60 wt. % Flax Fibers.*

CONCLUSIONS

From the analytical procedure we find that the properties of polyhydroxyalkanoate were enhanced after reinforced it by flax fibers. And the proportion of this improvement in properties associated with fiber's addition, where the higher wt. % of fibers will improve properties.

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